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SPECIAL ARTICLE

American College of Rheumatology Report on Reasonable Use of Musculoskeletal Ultrasonography in Rheumatology Clinical Practice

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Introduction

Musculoskeletal ultrasound (MSUS) has been embraced by many clinical rheumatologists, researchers in the field of rheumatology, and other subspecialists who treat rheumatology patients in the US and, to an even greater extent, in Europe. Its widespread adoption has been stimulated by its perceived utility for the diagnosis and management of rheumatic and musculoskeletal disorders and by claims that it enhances diagnosis and clinical outcomes.

Integration of MSUS into standard rheumatology practice raises numerous issues that relate to training, competence, reimbursement, and accreditation. In response to increasing member interest and experience in this area, the American College of Rheumatology (ACR) convened an MSUS Committee to carefully examine these issues and determine what role the ACR might play in future efforts to address them. During its deliberations, the Committee identified a need for formal, systematically developed guidance on appropriate use of MSUS in rheumatology practice. There is substantial literature on the topic of MSUS, but there was uncertainty over the quality and focus of that literature and whether it would be a sufficient

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base for such guidance. Therefore, to assist the MSUS Committee with its work, the ACR Board of Directors commissioned an MSUS study group to perform a literature synthesis, evaluate the quality of the evidence base, and use RAND/University of California at Los Angeles (UCLA) methodology to develop guidance on the use of MSUS in the setting of a clinical evaluation by a rheumatologist.

For this evaluation, the study group followed RAND/UCLA appropriateness methodology, a well-validated and highly refined process specifically intended to evaluate medical technology utilization in situations where the literature base may be incomplete. This method has been best validated for procedures with well-studied benefits and risks (1). By design, the RAND method excludes cost consideration of the procedure to focus on what is medically appropriate. Where risks of the procedure are minimal (or not well studied), as is the case with use of ultrasound, and because costs are not considered, the analysis will inherently favor use of the procedure. Therefore, rather than use the term "appropriate," which we felt would be overstating the findings, we use the term "reasonable" to mean that the evidence and/or consensus of the Task Force Panel (TFP) supported the use of MSUS for the described scenario.

Materials and methods

Overview. In the case of this project, deeming the "reasonable" uses of MSUS was predicated on the premise that the health benefits of the performance of MSUS in a rheumatology clinical setting outweigh any adverse consequences (1–3). The objective of this project was to evaluate the reasonable use of MSUS as an *additional* procedure in the setting of a rheumatologic evaluation, as evaluated by expert opinion and synthesis of the best available literature. It was not our goal to assess any *requirement* to perform MSUS, nor to make any inference about the quality of a regular rheumatologic assessment that does not employ MSUS.

Additional predicates of this exercise were that MSUS is performed by an operator properly trained in its use, *as part of an overall clinical evaluation in a rheumatology office that would include a history and physical examination* (i.e., point of care MSUS). It was not intended to include settings isolated from the rheumatologic assessment, such as might occur in a radiology department or operative setting, or other disciplines, such as podiatry or anesthesia. For our purposes, the possible use of MSUS in rheumatology practice was broadly defined and intended to include the diagnosis and treatment of inflammatory diseases as well as the range of noninflammatory and soft tissue disorders encountered in routine rheumatology clinical practice (e.g., rheumatoid arthritis, seronegative spondylarthritides, systemic lupus erythematosus, undifferentiated autoimmune disorders, adult-onset Still's disease, infectious arthritis, and crystal-induced arthritis, as well as joint or periarticular symptoms).

Our approach was based on established RAND/UCLA methodology, which uses a panel of experts to evaluate use of technologies and interventions in health care and has been well validated over time (2,3). The purpose of RAND/UCLA methodology is to reach a consensus among experts about situations for the potential use of a given technology for which the published evidence may not be sufficient for day-to-day clinical decision making. It utilizes groups of experts: a core expert panel (CEP) to generate case scenarios, to be evaluated by a TFP that votes on these scenarios informed by a systematic review of the literature.

We based our definition of *reasonable* on the RAND manual, which views a procedure as appropriate if "the expected health benefit exceeds the expected negative consequences by a sufficiently wide margin that the procedure is worth doing, exclusive of cost" (2,4). We ultimately opted to use the term "reasonable" rather than "appropriate" because the RAND/UCLA methodology excludes assessment of economic aspects, and the literature base is limited in respect to adverse consequences of performing or not performing MSUS.

Management of conflicts of interest. We required all individuals intellectually involved in this project to fully disclose their practice patterns with respect to MSUS, as well as any relationship with related industry or other organizations, and to update this information every 6 months or immediately following any change in status. We accomplished this through written disclosures that were shared with the full group and, in addition, for participants in the TFP meeting, through public verbal disclosure at the start of the meeting.

We managed the groups so that $<50\%$ of the participants in each of the 2 panels had any conflicts of interest at any time. Because use of MSUS in private practice might be a source of personal income, we viewed use of MSUS in private practice as a conflict that did not preclude participation but that did require balancing in the groups. Major conflicts, such as employment by a manufacturer of ultrasound equipment, precluded participation in this project. Also, in alignment with ACR policy, the corresponding author (TM) was unconflicted for the duration of this endeavor and for the subsequent 12 months.

A summary listing of all disclosures is available in Supplementary Appendix A (available in the online version of this article at http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2151-4658). Of note, all participant disclosures were shared online during the public comment period and throughout manuscript review. In addition, those who submitted public comments were asked to provide disclosures, and this information was reviewed as their comments were considered. A summary of public comments received is provided in Supplementary Appendix B (available in the online version of this article at http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2151-4658).

Expert panels. We recruited rheumatologists in private practice and academic settings, methodology experts, and a pediatric specialist, and we included a musculoskeletal radiologist and a patient. We assigned each of these individuals to 1 of 2 groups, either the CEP or the TFP. We

aimed for balance within each of these panels between MSUS users and those who do not routinely use ultrasound in clinical practice.

The CEP comprised the Chair (TM), a research librarian, professionals with methodologic expertise relating to the RAND process and clinical epidemiology, a radiologist, and rheumatologists with academic and/or practice experience in performance of MSUS. Within this panel were working groups tasked to help develop the clinical scenarios and perform the literature search and systematic review. The literature search working group was directed by the lead literature review investigator (JF) and included a senior research librarian and a cadre of abstractors.

The TFP comprised rheumatologists with a range of pertinent expertise that included clinical research, guideline development, academic interest in MSUS, and use of MSUS in various practice settings; a pediatric rheumatologist; and a patient representative.

Development of clinical scenarios. We commenced by compiling an inventory of potential uses of MSUS in rheumatology practice, based on literature and expert views. A subgroup of CEP members then used this to develop an exhaustive series of scenarios in rheumatology clinical practice in which MSUS could be utilized. This list was posted online for public comment and then refined iteratively through a process of feedback and critique from all CEP members to derive consensus on a set of scenarios for later evaluation and voting by the TFP (see Supplementary Appendix C, available in the online version of this article at http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2151-4658). The scenario questions were qualified with a list of anatomic sites, including articular and periarticular regions.

Literature search. The systematic review was directed by the lead literature review investigator (JF), with literature identification by a senior research librarian, to provide data pertinent to the use of MSUS for each of the clinical scenarios. For consideration, articles had to be published in English in 1990 or later, have an abstract, and present original research in humans evaluating MSUS in a setting reflective of rheumatologic practice for any of the prespecified clinical scenarios. We did not include review articles, letters, comments, editorials, case reports and case series with <6 subjects, or evaluations of emerging MSUS technologies such as magnetic resonance imaging (MRI)/MSUS or computed tomography/MSUS fusion images, 3-dimensional MSUS imaging, and arthroscopic MSUS. Therefore, we did not include articles about MSUS procedures performed primarily by nonrheumatologists (e.g., nerve block for anesthesia) or outside of the routine rheumatology scope of practice (e.g., diagnosis of hip dysplasia).

We performed searches using the Ovid system, Medline, Medline in-process and other non-indexed citations, and Embase databases (Embase contains references of conference abstracts as well as published articles). An initial search using the Wiley Cochrane Central Register of Controlled Trials was conducted on August 24, 2011, and a search for additional topics (giant cell arteritis and myositis) was performed September 15, 2011.

We classified the publications into 1 of 4 major categories derived from the clinical scenarios defined above, including 1) procedure guidance, 2) monitoring disease activity and progression, 3) reliability studies, and 4) other diagnoses.

The abstraction process was divided into 3 stages: 1) title review, 2) review of the abstract, and 3) evaluation and abstraction of data from the manuscript. Each title and abstract was reviewed by 2 abstractors for inclusion/exclusion criteria. Disagreements were resolved by discussion and, if necessary, adjudicated by the lead investigator. Then, each article was abstracted by a single reviewer using an abstraction table and summary template guide. These were compiled into a literature summary. More details about the literature search strategy can be found in Supplementary Appendix D (available in the online version of this article at http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2151-4658).

Public comment. Before it was finalized, the drafted list of clinical scenarios in which MSUS might be used in rheumatology practice was posted online at the ACR web site (www.rheumatology.org) in August 2011. Also posted was a project protocol that included descriptions of the project background and scope, methodology, composition of the development group, disclosure and conflict of interest, publication and authorship, timeline, and ACR staff contacts. An e-mail was then sent to the ACR membership, requesting their feedback via an online public comment mechanism, with 2 weeks allowed for responses about any specific part of the protocol or the project in general. One reminder e-mail was sent to encourage comments. Twenty-four responses were received and considered when finalizing the clinical scenarios for later use in TFP voting. All respondents identified themselves and either provided disclosure or declared that they had nothing to disclose.

Voting methodology. When the TFP voted, we instructed them to focus on benefits and risks in their evaluation of the use of MSUS for each clinical scenario, per the RAND methodology. Possible benefits that we highlighted related to enhanced accuracy and speed of diagnosis, patient comfort, and improved patient outcomes. Possible risks related to procedural discomfort, errors due to poor diagnostic performance, and consequent inappropriate treatment, as well as overutilization of resources. There were 2 rounds of voting in which the members of the TFP ranked the appropriateness of the use of MSUS for each of the clinical scenarios on a Likert scale ranging from 1–9, in which 1–3 was considered "inappropriate" (risks clearly outweigh the benefits), 4–6 was considered "uncertain," and 7–9 was considered "appropriate" (benefits clearly outweigh the risks). The first round of voting took place electronically, prior to a face-to-face meeting, where the second round of voting was conducted following a discussion of the round 1 scores in relation to pertinent literature. We provided the list of possible benefits and risks to

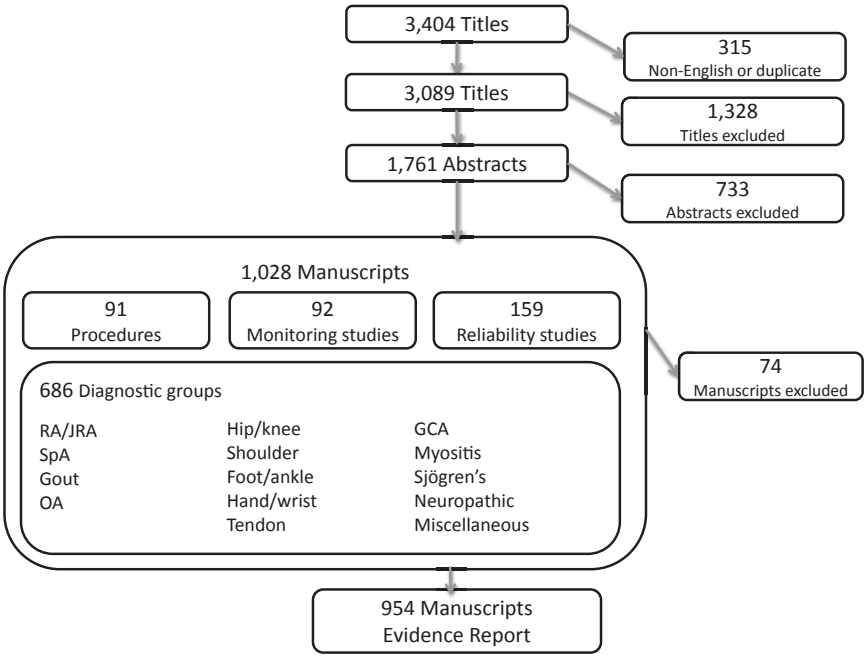

Figure 1. Overview of the flow of the literature search and abstraction process. RA = rheumatoid arthritis; JRA = juvenile RA; SpA = spondylarthritis; OA = osteoarthritis; GCA = giant cell arteritis.

the panel prior to round 1 voting and displayed them in the meeting room for round 2 voting (see Supplementary Appendix E, available in the online version of this article at http://onlinelibrary.wiley.com/journal/10.1002/(ISSN)2151-4658). Prior to each vote, we verbally reminded the experts of the mandate to focus on benefits and risks.

Developing recommendations from votes by the TFP and grading the evidence. Case scenarios were translated into positive recommendations (i.e., deemed "reasonable") when both of the following criteria were met: 1) the median round 2 voting scores were between 7 and 9, and 2) there was no significant disagreement, defined as no more than one-third of the TFP voting below the level of 4, in that question. Case scenarios were translated into negative recommendations (i.e., deemed "not reasonable") when the reverse criteria were met: 1) the median round 2 voting scores were between 1 and 3, and 2) there was no significant disagreement, defined as no more than one-third of the TFP voting above the level of 6, in that question. If the median round 2 voting score was between 4 and 6 for a clinical scenario, the opinion of the panel was deemed "uncertain"; in this case, neither a positive nor a negative recommendation was made. We concatenated scenarios where the voting results were highly collinear.

In the following section, we supplement the recommendations derived from TFP votes with an indication of the level of supporting evidence in the literature based on established methodology used by the American College of Cardiology (5) and applied to other recent ACR recommendations (6,7), in which level A grading classifies recommendations supported by more than 1 randomized clinical trial, or 1 or more meta-analyses of randomized clinical trials; level B grading by a single randomized trial, nonrandomized studies, or meta-analysis of nonrandomized studies; and level C grading by consensus opinion of experts, case studies, or standard of care. In addition, we provide a summary of panel discussion and cite pertinent articles that informed and influenced voting.

Results

Literature search and systematic review. An overview of the flow of the literature search and abstraction process is shown in Figure 1.

Clinical scenarios supported by evidence and consensus opinion (Table 1).

1. For a patient with articular pain, swelling, or mechanical symptoms, without definitive diagnosis on clinical examination, it is reasonable to use MSUS to further elucidate the diagnosis at the following joints: glenohumeral, acromioclavicular, sternoclavicular, elbow, wrist, metacarpophalangeal, interphalangeal, hip, knee, ankle, midfoot, and metatarsophalangeal. However, performing MSUS at the temporomandibular joint (TMJ) and costochondral joints will not add to the clinical assessment (level of evidence B).

MSUS can reliably identify numerous features of articular disease, some of which cannot be detected by clinical examination, others of which can be evaluated by MSUS with greater sensitivity. MSUS can reliably (8) identify pathologic features of gout (9–11), chondrocalcinosis (12,13), features of osteoarthritis and inflammatory arthritides (14), including synovial and bursal effusion, and synovial hypertrophy (15). MSUS can identify rheumatoid

Table 1. Summary of clinical scenarios achieving mainly positive recommendations*

	Level of evidence
1. For a patient with articular pain, swelling, or mechanical symptoms, without definitive diagnosis on clinical examination, it is reasonable to use MSUS to further elucidate the diagnosis at the following joints: glenohumeral, acromioclavicular, sternoclavicular, elbow, wrist, metacarpophalangeal, interphalangeal, hip, knee, ankle, midfoot, and metatarsophalangeal. However, performing MSUS at the TMJ and costochondral joints will not add to the clinical assessment.	B
2. For a patient with mono- or oligoarthralgia, current or historical, without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate for evidence of subclinical inflammatory arthritis or enthesitis at the following asymptomatic joints or regions: glenohumeral, acromioclavicular, sternoclavicular, elbow, wrist, metacarpophalangeal, interphalangeal, hip, knee, ankle, midfoot, and metatarsophalangeal.	B
3. For a patient with diagnosed inflammatory arthritis and new or ongoing symptoms without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate for inflammatory disease activity, structural damage, or emergence of an alternate cause at the following sites: glenohumeral, acromioclavicular, elbow, wrist, metacarpophalangeal, interphalangeal, hip, knee, ankle, midfoot and metatarsophalangeal, and entheseal.	B
4. For a patient with pain or mechanical symptoms of the hip region without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate effusion, intraarticular and periarticular lesions, and adjacent regional soft tissue structures.	B
5. For a patient with periarticular pain without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate tendon and soft tissue pathologies and the nature and localization of adjacent swelling at the shoulder, elbow, hand, hip, knee, ankle, and forefoot.	B
6. For a patient with inflammatory-sounding entheseal, sacroiliac, or spine pain, it is reasonable to use MSUS to evaluate for evidence of enthesopathy.	B
7. For a patient with shoulder pain or mechanical symptoms, without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate underlying structural disorders, but not for adhesive capsulitis or as preparation for surgical intervention.	B
8. For a patient with regional mechanical symptoms, without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate for inflammation, tendon, and soft tissue pathologies at the following regions: shoulder, elbow, hand, wrist, hip, knee, ankle, and foot.	B
9. It is reasonable to use MSUS to evaluate the parotid and submandibular glands in a patient being evaluated for Sjögren's disease to determine whether they have typical changes as further evidence of the disorder.	B
10. For a patient with symptoms in the region of a joint whose evaluation is obfuscated by adipose or other local derangements of soft tissue, it is reasonable to use MSUS to facilitate clinical assessment at the glenohumeral, acromioclavicular, elbow, wrist, hand, metacarpophalangeal, interphalangeal, hip, knee, ankle/foot, and metatarsophalangeal joints.	C
11. For a patient with regional neuropathic pain without definitive diagnosis on clinical examination, it is reasonable to use MSUS to diagnose entrapment of the median nerve at the carpal tunnel, the ulnar nerve at the cubital tunnel, and the posterior tibial nerve at the tarsal tunnel.	B
12. It is reasonable to use MSUS to guide articular and periarticular aspiration or injection at sites that include the synovial, tenosynovial, bursal, peritendinous, and perientheseal areas.	A
13. Use of MSUS may be reasonable for guidance during synovial biopsy procedures.	C
14. It may be reasonable to use MSUS to monitor disease activity and structural progression at the glenohumeral, acromioclavicular, elbow, wrist, hand, metacarpophalangeal, interphalangeal, hip, knee, ankle, foot, and metatarsophalangeal sites in patients with inflammatory polyarthritis.	B

* MSUS = musculoskeletal ultrasound; TMJ = temporomandibular joint.

nodules and discriminate these from tophi and fluid-filled structures (16). Observational studies show that MSUS performs better than clinical examination in establishing the presence of articular effusion (17–20); can reliably detect and quantify inflammation in the synovium (21) and other structures, even when not clinically apparent (10); and can change the clinical evaluative approach (19). Therefore, the perceived potential benefits of MSUS for this clinical scenario relate to its potential to expedite diagnosis and implementation of treatment at the point of care, and possibly reduce the need for other costly or hazardous imaging procedures (22,23).

With respect to possible harms, there is a theoretical possibility that high sensitivity of MSUS for some features such as erosions or urate deposits (11,14,24) could lead to overdiagnosis; however, the dominant TFP discussion of MSUS limitations in this clinical scenario related to the attempted use of MSUS at an anatomic site at which its windowing capabilities are constrained by technological considerations. For example, a substantial proportion of the TMJ cannot be imaged by MSUS due to interposition of bone. Therefore, use of MSUS at the TMJ and costochondral joints did not achieve scores sufficient for recommendation.

2. For a patient with mono- or oligoarthralgia, current or historical, without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate for evidence of subclinical inflammatory arthritis or enthesitis at the following asymptomatic joints or regions: glenohumeral, acromioclavicular, sternoclavicular, elbow, wrist, metacarpophalangeal, interphalangeal, hip, knee, ankle, midfoot, and metatarsophalangeal (level of evidence B).

MSUS can detect features of inflammation in joints and entheses where this was not clinically apparent. The most compelling evidence for this supposition derives from studies of gout demonstrating that ultrasonographic features of urate crystals (8,9) may be present in asymptomatic joints (10,14), thus aiding the diagnosis. Calcium pyrophosphate dihydrate disease can also be detected by MSUS and distinguished from uric acid deposits based on typical characteristics (12,13). MSUS can detect rheumatoid erosions and synovial inflammation in asymptomatic joints and inflammation around asymptomatic entheses of patients with spondylarthropathy (25–31).

3. For a patient with diagnosed inflammatory arthritis and new or ongoing symptoms without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate for inflammatory disease activity, structural damage, or emergence of an alternate cause at the following sites: glenohumeral, acromioclavicular, elbow, wrist, metacarpophalangeal, interphalangeal, hip, knee, ankle, midfoot and metatarsophalangeal, and entheseal (level of evidence B).

Because the issue in question related to the ability of MSUS to elucidate or confirm rheumatic disease processes in articular sites, the evidence base utilized was similar to that for recommendations 1 and 2. However, the consequence of this nuance on the voting was that the possible benefit would be optimization of the treatment regimen rather than diagnostic (although an additional diagnosis could theoretically emerge). Additional indications for MSUS include the prognostic value of MSUS findings (see recommendation 14 below for further detail).

The influential studies for this question are those that show the capability of MSUS to detect inflammatory processes such as erosions, synovitis, and enthesitis, especially in situations where this was clinically not appreciated or seen on plain radiographs (21,32–37). While the majority of studies described the benefit of MSUS complementing clinical examination and radiography, some studies suggested that MSUS was not as sensitive as radiography (10,38,39).

4. For a patient with pain or mechanical symptoms of the hip region without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate effusion, intraarticular and periarticular lesions, and adjacent regional soft tissue structures (level of evidence B).

Because of the anatomic depth of the hip joint and consequent difficulties in its clinical evaluation, MSUS has the potential for great diagnostic utility at this site. Observational studies have demonstrated its utility in detecting effusion and synovial hypertrophy in various situations, including rheumatoid arthritis and juvenile idiopathic arthritis (20,40–45), one of which demonstrated considerably greater sensitivity of MSUS compared to radiography in patients with an irritable hip (71% versus 15%) (45). Case series have also described the success of dynamic ultrasound in diagnosing various causes of external snapping hip, relating to the iliotibial band, gluteal muscle (46), iliopsoas tendon, bifid tendon heads, tendon impingement on an anterior paralabral cyst, and labral tears (47,48), and other tendinopathies (49–52).

5. For a patient with periarticular pain without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate tendon and soft tissue pathologies and the nature and localization of adjacent swelling at the shoulder, elbow, hand, hip, knee, ankle, and forefoot (level of evidence B).

Case series show the utility of MSUS in evaluating elbow periarticular pathologies such as olecranon bursal fluid, synovial proliferation, triceps tendinitis, and calcification (15,53), although interobserver reliability has not always been high (54). One case–control study of medial epicondylitis (55) showed that MSUS had good agreement with physical examination (as the gold standard), with 95% sensitivity, 92% specificity, 90% positive predictive value, and 95% negative predictive value. MSUS may also be useful in detecting digital tendon pathologies (56–58). One study compared MSUS to MRI in detection of digital flexor tendinopathy and found sensitivity of 33% for partial tears and 67% for complete tears, and specificity of 89% for partial tears and 100% for complete tears (59). MSUS studies evaluating patellar tendinopathy have been performed but are limited in generalizability and data on diagnostic test performance (60–64).

Numerous studies support the use of MSUS in evaluating periarticular structures of the ankle. One study compared the diagnostic accuracy of MSUS in evaluating posterior tibial tendinopathy with MRI and found the tests to be comparable (sensitivity 0.83, specificity 0.90) (65).

MSUS features of Achilles tendinopathy are also well described (66–68), as are those of plantar fasciitis. A systematic review of 23 studies (69) showed that plantar fascia thickness was the most common MSUS finding.

MSUS can differentiate rheumatoid nodules from tophi (16), and it has good diagnostic accuracy for wrist ganglia (70). In a case series, MSUS identified 13 of 23 cystic lesions of digital ganglia (71).

6. For a patient with inflammatory-sounding entheseal, sacroiliac, or spine pain, it is reasonable to use MSUS to evaluate for evidence of enthesopathy (level of evidence B).

There are numerous articles describing the MSUS features of spondylarthropathy and the utility of imaging the enthesis to establish this diagnosis (72–80). The identification of entheseal inflammation by MSUS in patients with symptoms suggestive of spondylarthropathy has been shown to be predictive of the subsequent diagnosis (e.g., sensitivity 0.76, specificity 0.81, odds ratio 14.1) (25–31). Other studies in this area using a variety of design methodologies have had broadly similar results (26,27,29–31), albeit with some exceptions (28).

7. For a patient with shoulder pain or mechanical symptoms, without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate underlying structural disorders, but not for adhesive capsulitis or as preparation for surgical intervention (level of evidence B).

There is a considerable body of literature evaluating the performance of MSUS in clinical assessment of shoulder pain due to soft tissue and subacromial disorders, including 3 systematic reviews (81–83). In an analysis of the results of 23 studies comparing MSUS versus MRI (81), the diagnostic performance of MSUS for rotator cuff tears was as follows: sensitivity 0.95 (95% confidence interval [95% CI] 0.90–0.97) and specificity 0.96 (95% CI 0.93–0.98) for full-thickness supraspinatus tears, and sensitivity 0.72 (95% CI 0.58–0.83) and specificity 0.93 (95% CI 0.89–0.96) for partial-thickness tears. For subacromial bursitis, sensitivity ranged from 0.79–0.81 and specificity ranged from 0.94–0.98. For tendinopathy, sensitivity ranged from 0.67–0.93 and specificity ranged from 0.88–1.00. Sensitivity for calcific tendinitis was 1.00 in both studies, with specificity ranging from 0.85–0.98. Similar findings had previously been cited in an earlier systematic review (82). The studies they reviewed also demonstrated the ability to detect glenohumeral effusions. They concluded that MSUS can differentiate inflammatory from noninflammatory pathologies of the biceps tendon sheath (84) and measure displacement of the coracoacromial ligament (85) and thickening of the supraspinatus and biceps tendons (86).

8. For a patient with regional mechanical symptoms, without definitive diagnosis on clinical examination, it is reasonable to use MSUS to evaluate for inflammation, tendon, and soft tissue pathologies at the following regions: shoulder, elbow, hand, wrist, hip, knee, ankle, and foot (level of evidence B).

The evidence base and rationale for this proposition are represented in recommendations 4, 5, and 7. MSUS can identify a number of pathologies that could account for such symptoms, including fluid collections, edema, hyperemia, tophi, rheumatoid nodules, foreign bodies, muscle edema and hyperemia, tendon and ligament inflammation or disruption, and internal articular derangement (loose bodies, effusion, articular osseous and cartilaginous irregularities, irregularities of ligaments and tendons, presence of plicae, and subluxation of such structures). The panel viewed the benefits of MSUS in this scenario as facilitating or accelerating diagnosis.

9. It is reasonable to use MSUS to evaluate the parotid and submandibular glands in a patient being evaluated for Sjögren's disease to determine whether they have typical changes as further evidence of the disorder (level of evidence B).

Ultrasonography of the salivary glands has been widely tested against other benchmarks, such as sialography, MRI, scintigraphy, and histopathology, and against different clinical examinations and serologic definitions of Sjögren's syndrome (87–93). These studies have consistently demonstrated high specificity for Sjögren's syndrome in the range of 0.83–1.0 (87–93). One of these studies compared ultrasonography with parotid MRI and MR sialography and found the specificity of ultrasonography to be the highest, at 0.94 (94). Estimates of sensitivity have been lower and more variable (range 0.43–0.90) (88,91,92,95–98). In the comparison against MRI, MR sialography was the best (0.96), followed by parotid MRI (0.81) and ultrasonography (0.78) (94). Another study compared ultrasonography of the salivary glands with contrast sialography and scintigraphy using a receiver operating characteristic curve analysis (99). Their results suggested that ultrasonography was the best diagnostic test, with sensitivity (75.3%), specificity (83.5%), and a positive likelihood ratio of 4.6. The high specificity supports its role as a first-step evaluation in patients with suspected Sjögren's syndrome.

10. For a patient with symptoms in the region of a joint whose evaluation is obfuscated by adipose or other local derangements of soft tissue, it is reasonable to use MSUS to facilitate clinical assessment at the glenohumeral, acromioclavicular, elbow, wrist, hand, metacarpophalangeal, interphalangeal, hip, knee, ankle/foot, and metatarsophalangeal joints (level of evidence C).

The panel decision making for this scenario was driven by the technical capability of MSUS technology to image deep structures and identify musculoskeletal abnormalities at those sites. Because there were no MSUS studies specifically addressing adiposity, the judgments were based on expert experience.

11. For a patient with regional neuropathic pain without definitive diagnosis on clinical examination, it is reasonable to use MSUS to diagnose entrapment of the median nerve at the carpal tunnel, the ulnar nerve at the cubital tunnel, and the posterior tibial nerve at the tarsal tunnel (level of evidence B).

Numerous studies have evaluated the performance of MSUS for diagnosis of carpal tunnel syndrome (CTS), including 2 systematic reviews (100,101). Increased cross-sectional area of the median nerve is a repeatable and reliable measurement and is predictive of CTS (102–105), with sensitivity generally in the range of 0.82–0.98 and specificity of 0.87–1.0 (98,106–109). In observational studies, the diagnostic performance of MSUS appears to be superior to clinical examination findings (110) and has comparable performance to nerve conduction studies (111,112), albeit with some inconsistencies (113–115). Ongoing refinements to the MSUS measurement approach may increase its diagnostic accuracy (116,117).

MSUS can also be used to assess severity of CTS. In various studies, the cross-sectional area of the median nerve has been correlated with clinical severity, pain, hand function, and electrophysiologic severity (118–120). One other study, however, found electrophysiologic measurements to be better predictors of symptom severity and functional status in idiopathic CTS (121). In contrast, studies evaluating the ability of MSUS to predict response to carpal tunnel decompression have had mixed or poor results (122–124).

Three case–control studies of ulnar neuropathy diagnosed by electrodiagnostic studies found that the maximal cross-sectional area is predictive of this diagnosis, with sensitivity ranging from 0.88–0.95 and specificity ranging from 0.71–1.00 (125–127). Another prospective controlled study demonstrated MSUS to have sensitivity and specificity of 0.80 and 0.91, respectively (128).

MSUS is also reported to be of use in the diagnosis of posterior tibial nerve entrapment (129).

12. It is reasonable to use MSUS to guide articular and periarticular aspiration or injection at sites that include

the synovial, tenosynovial, bursal, peritendinous, and perientheseal areas (level of evidence A).

MSUS guidance provides more accurate needle placement than palpation at sites that include the knee, where MSUS-guided injection accuracy ranges from 91–97% (75,130–133), compared to palpation-guided injection accuracy of 40–92% (133). Similar studies show better accuracy for the acromioclavicular joint injection (95–100% versus 40–72% accuracy) (134,135), pes anserine bursa (136), flexor digitorum tendon sheath (137), flexor hallucis longus, posterior tibial tendon and peri-Achilles space (138), tarsometatarsal joints (139), sinus tarsi (140), and tibiofibular joint (141). MSUS facilitates accurate needle placement into the peroneal tendon sheath (142), subacromial bursa (143), metatarsophalangeal joints, tibiotalar joint, peri-Achilles space, flexor hallucis longus sheath, posterior tibial tendon sheath, subtalar joint (138), TMJ (144), sacroiliac joint (74,145,146), and facet joints (147–149).

MSUS procedure guidance also appears to improve clinical outcomes (130,150–154) at sites, including the glenohumeral joint (153,154) or subacromial bursa (155,156), knee (visual analog scale [VAS] improvement of 4.9 for palpation guidance versus 6.0 for US guidance) (157), and sacroiliac joint (74,145,146). MSUS guidance may also permit more effective injection of Morton's neuroma (158). Results have been mixed for plantar fascia injection (159,160) and negative for the wrist joint (152).

Arthrocentesis procedural pain appears to be less when performed with MSUS guidance (131). In 3 studies, palpation-guided injection was associated with VAS pain levels ranging from 4.8–5.8 compared to 2.7–3.7 with MSUS guidance (all comparisons reached statistical significance) (150,151,157).

The ability of MSUS to aspirate or drain structures not reliably accessible without imaging guidance has been confirmed for hip joints (161–166), Baker's cysts (167), shoulder ganglion cysts (168), intramuscular ganglia (169), and meniscal cysts (170). On the other hand, studies of the value of MSUS guidance for aspiration of soft tissue infections have produced mixed results (171,172).

Case series also report favorably on the use of MSUS guidance in less commonly performed procedures, such as percutaneous tenotomy for chronic tendinosis at the lateral epicondyle (173,174), tenotomy for infrapatellar tendinopathy (175), and barbotage for treatment of chronic calcific tendinosis in the rotator cuff (176–184). MSUS has also been used for corticosteroid injection of CTS with clinical benefit, but has not yet been compared to palpation-guided injections of the carpal tunnel (185).

13. Use of MSUS may be reasonable for guidance during synovial biopsy procedures (level of evidence C).

MSUS can image the synovium and appears to increase the yield of biopsies at various joint sites in research reports, albeit only in reference to historical data (186–188). The fact that the biopsy yield from blind (unguided) procedures has historically been very low was influential in the panel decision making.

14. It may be reasonable to use MSUS to monitor disease activity and structural progression at the glenohumeral, acromioclavicular, elbow, wrist, hand, metacarpophalangeal, interphalangeal, hip, knee, ankle, foot, and metatarsophalangeal sites in patients with inflammatory polyarthritis (level of evidence B).

There are more than 30 studies examining the role of MSUS in monitoring disease activity in response to therapeutic interventions. MSUS measures of articular inflammation are reliable (189) and responsive to corticosteroid interventions at a range of sites, including the wrist, elbow, proximal interphalangeal, talocrural, metacarpophalangeal, metatarsophalangeal, knee, and sternoclavicular joints (190–196), and in various forms of arthritis (197). Some studies have also evaluated the responsiveness of MSUS entheseal changes to therapy in patients with spondylarthropathy (198–200). The largest study evaluated the cumulative MSUS score and showed a significant decrease from baseline to 6 months after treatment with a tumor necrosis factor (TNF) inhibitor (199,200).

MSUS features, particularly power Doppler, correlate with radiographic progression of rheumatoid arthritis erosions and predict subsequent development of erosions (21,189,201–203). All of these MSUS measures of joint inflammation also demonstrate some degree of responsiveness to therapeutic intervention, albeit with some variability among the exact measures tested (200,201,204–214). There have been similar results for its use in monitoring intra- and perientheseal disease activity in patients with spondylarthritides treated with anti-TNFα therapy (215). As a result, there are now ongoing endeavors to develop and validate MSUS-based inflammatory arthritis disease activity scoring systems (reviewed recently by Mandl et al [216]) and definitions of clinical remission (217–227).

Clinical scenarios not supported by evidence or consensus opinion. Concern arose in the consideration of MSUS in evaluating giant cell arteritis. Meta-analyses suggest sensitivity of ~68–75% and specificity of 83–91% (228,229), and tester reliability can be good (interreader $\kappa = 0.85$, intrareader $\kappa = 0.95$) (230). However, given the infrequent opportunity to perform this examination, there was concern about potential operator proficiency; the high risk of missing a diagnosis and the imperfect sensitivity of the test generated considerable concern among the panelists about its use.

Other scenarios for which MSUS did not achieve a recommendation included evaluation of shoulder capsulitis, eosinophilic fasciitis, myositis, numerous sites of nerve entrapment (other than the median nerve at the carpal tunnel, the ulnar nerve at the cubital tunnel, and the posterior tibial nerve at the tarsal tunnel), and outcome measurement for OA. Additional concerns related to the limits of the technology in imaging sites such as the deep aspects of the sternoclavicular and costochondral joints.

Discussion

The literature base on MSUS is large but mostly consists of observational material, with few trials evaluating patient outcomes or using randomization to control for potential biases. Furthermore, with few health risks from the procedure and few meaningful studies evaluating the potential risks of misdiagnosis or costs, the TFP was left to consider

primarily theoretical risks of MSUS. However, the RAND/UCLA methodology is explicitly designed for derivation of recommendations for procedure utilization in settings where the data are incomplete. This process integrates professional experience with the best available evidence and an iterative voting process. Representation of experts on the voting panel is, therefore, critical to the process, but we were careful to also include physicians with methodologic expertise as well as a patient advocate. Also, because there may be a relative conflict of interest related to practicing in settings in which MSUS could theoretically generate revenue, we constrained such professionals to less than 50% of the panel.

Nevertheless, because of the rather low level of evidence in general, and the absence of cost-effectiveness studies, our recommendations should be viewed with a number of important caveats. In particular, we evaluated the use of MSUS in the setting of rheumatology practice, in which it is performed *as part of a clinical evaluation* by a rheumatologist, and operated by a professional adequately trained in its use. Consequently, our recommendations should not be generalized to settings or points of care isolated from the rheumatologic assessment, such as might occur in a radiology department. Also, we did not consider the potential risks related to the misapplication of MSUS by individuals not adequately trained in its use. A related issue is that there are currently no established benchmarks for determining proficiency in MSUS use by a rheumatologist in this setting. Certification of individual practitioners in MSUS is not currently available in the US, but is scheduled to become available through the American Registry for Diagnostic Medical Sonography. However, that certification program is not specifically focused on point of care MSUS, so development of a MSUS certification program for rheumatologic practice is desirable.

In addition, we framed most of the scenarios to reflect situations in which the clinical evaluation had some uncertainty, so that MSUS could add to the diagnostic process. *The use of MSUS was viewed by the panel as a complementary procedure and not as an alternative to systematic clinical evaluation.* One consequence of this approach is that in none of the recommendations do we advocate for the use of MSUS when the clinical evaluation has already established a diagnosis with a high level of confidence.

Within this framework, the product of this extensive endeavor is a broad endorsement of the applicability of MSUS as a reasonable but not mandatory component of rheumatologic practice. The panel viewed MSUS as having substantial potential benefits with regard to enhancing point of care diagnosis, accelerating implementation of treatment, and possibly reducing utilization of other onerous imaging tests, such as MRI. Risks were not prominent because of the inherent safety of the technology, but there was acknowledgment of technological limitations and possible misclassification.

Although the panel viewed the use of MSUS as reasonable for a large number of scenarios, it is important to note that the votes for many scenarios did not meet this threshold. These generally occurred because of concerns about the risks (e.g., for evaluation of the temporal arteries for giant cell arteritis) or because of technological limitations of ultrasound.

Finally, despite the strengths of the RAND/UCLA methodology, this method seeks to define appropriateness and effectiveness of the procedure in isolation of cost considerations. To our knowledge, there are few cost-effectiveness or cost–benefit studies. However, these studies have demonstrated that ultrasound-guided knee injections can save money over palpation-guided injections by prolonging time to reinjection (150). Others demonstrated cost savings of MSUS over MRI through reduced utilization, reduced time to diagnosis (22), and reduced number of visits to treat the condition (23,231). Nevertheless, cost consideration is necessary to guide use and mitigate societal risks through overutilization and consumption of health care resources. More research is needed in this area to determine the value of MSUS relative to other health care interventions.

Our findings, together with practice trends in the US and in Europe, foresee the likelihood of increased adoption of this technology in rheumatology. Indeed, MSUS-based criteria are already proposed in several disease set criteria such as for classification of polymyalgia rheumatica (232) and rheumatoid disease activity scales (216). These trends predicate a professional and research agenda that includes formulation of practice training resources and standards, and evaluation of other important aspects of the performance of MSUS, such as cost-effectiveness and impact on long-term outcomes.

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All authors were involved in drafting the article or revising it critically for important intellectual content, and all authors approved the final version to be published. Dr. McAlindon had full access to all of the data in the study and takes responsibility for the integrity of the data and the accuracy of the data analysis.

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