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Title. The 2017 EULAR standardised procedures for ultrasound imaging in rheumatology

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ABSTRACT

Background. In 2001, EULAR developed and disseminated the first guidelines for musculoskeletal (MS) ultrasound (US) in rheumatology. Fifteen years later, the dramatic expansion of new data on MSUS in the literature coupled with technological developments in US imaging have necessitated an update of these guidelines.

Objectives. To update the existing MSUS guidelines in rheumatology as well as to extend their scope to other anatomic structures relevant for rheumatology.

Methods. The project consisted of the following steps: 1. A systematic literature review of MSUS evaluable structures; 2. A Delphi survey among rheumatologists and radiologists expert in MSUS to select MS and non-MS anatomic structures evaluable by US that are relevant to rheumatology, to select abnormalities evaluable by US and to prioritize these pathologies for rheumatology; 3. A nominal group technique to achieve consensus on the US scanning procedures and to produce an electronic illustrated manual [i.e. application (App)] of these procedures.

Results. Structures from nine MS and non-MS areas (i.e. shoulder, elbow, wrist and hand, hip, knee, ankle and foot, peripheral nerves, salivary glands, and vessels) were selected for MSUS in rheumatic and musculoskeletal diseases (RMD) and their detailed scanning procedures (i.e. patient position, probe placement, scanning method and bony/other landmarks) were used to produce the App. In addition, US-evaluable abnormalities present in RMD for each anatomic structure and their relevance for rheumatology were agreed on by the MSUS experts.

Conclusions. This task force has produced a consensus-based comprehensive and practical framework on standardised procedures for MSUS imaging in rheumatology.

Introduction

Over the last two decades, increasing numbers of rheumatologists worldwide have incorporated musculoskeletal (MS) ultrasound (US) into their clinical practice both as a valuable diagnostic and monitoring tool (1-6) and a means to guide interventions (injections and biopsies) (7,8). MSUS is a multiplanar and dynamic imaging modality. It has a number of benefits over other imaging techniques; of particular note is safe and well tolerated by patients and provides point of care scanning allowing immediate and direct correlations between imaging findings and clinical data, which can improve the management of patients with rheumatic and musculoskeletal diseases (RMD). The increasing miniaturisation of scanning machines and hence portability have improved access to the use of MSUS in different clinical settings. MSUS has been applied to a wide range of RMD including inflammatory and degenerative joint diseases, crystal arthropathy, connective tissue diseases, vasculitis and regional pain syndromes.

In 2001, the European league Against Rheumatism (EULAR) developed and disseminated the first Guidelines for Musculoskeletal Ultrasound in Rheumatology based both on the available literature at the time and the expert opinion of a panel of European rheumatologists highly experienced in MSUS (9). These guidelines set the technical standards for the use of MSUS in rheumatology and established a standardized MSUS scanning method in RMD. They have been widely used in clinical practice and research by the rheumatology community and have been widely cited in the literature. However, since their inception, there has been significant developments in technology and an increasing literature base with respect to validation and clinical application of MSUS for RMD, including the first incorporation of MSUS findings in rheumatologic disease classification criteria (10-13). Furthermore, scientific rheumatology and radiology societies such as EULAR, the American College of Rheumatology (ACR), the Pan American League of Association for Rheumatology (PANLAR), and the European Society of Musculoskeletal Radiology (ESSR) have produced evidence and expert opinion-based recommendations on the use of MSUS in the clinical management of RMD (14-19).

To this end, a new EULAR-endorsed task force was created with the following objectives:
1. To update the standardized scanning procedures (i.e. patient position, probe placement, scanning method) for MSUS assessment of the joint areas accessible to US evaluation involved in RMD;
2. To produce standardized imaging procedures (i.e. patient position, probe placement, scanning method) for US assessment of other articular and non-articular accessible anatomic structures of importance in rheumatology; and
3. To select and prioritize the abnormalities evaluable by MSUS present in RMD;
4. To create an electronic illustrated manual [i.e. application (App)] of these images and techniques procedures accessible to all with interest in performing MSUS in their practice.

Methods

The task force was composed of a steering group [i.e. the convenors (IM and MB), two rheumatologists with high expertise in MSUS and anatomy (EN and DB), the methodologist (LC) and two fellows (IJ and SO)] and a panel consisting of 28 rheumatologists and radiologists highly experienced in MSUS performance, teaching and research in RMD. These task force members have been involved in education in MSUS within EULAR and in international multicentre research projects under the OMERACT (Outcome Measures in Rheumatology) initiative over the past 10-15 years and have worked and published on standardisation of MSUS scanning methods and definitions and criteria for MSUS abnormalities. In addition, the task force included two health professionals (HP) experienced

in MSUS [i.e. a podiatrist (HS) and a radiographer (GS)] and one patient representative (DH). The members of the task force represented 22 countries in Europe, the Americas and Asia (Austria, Bulgaria, Canada, Colombia, Denmark, France, Finland, Germany, Hungary, Hong Kong, Ireland, Italy, México, Netherlands, Norway, Poland, Romania, Serbia, Spain, United Kingdom, United States of America, and Venezuela).

The project consisted of the following steps: 1. A systematic scoping review (SSR) on how MSUS is performed and what pathologies can be assessed by MSUS in RMD; 2. A Delphi survey aiming at selecting MS and non-MS anatomic structures evaluable by US and relevant to RMD, selecting pathologies evaluable by US and prioritizing these abnormalities for rheumatology; 3. A nominal group technique was convened to achieve consensus on the scanning procedures summarised from the literature review for the MS and non-MS anatomic structures selected in the previous Delphi step and to produce the corresponding images for the EULAR US Scanning App.

Scoping review

A scoping literature review was performed by two fellows (IJ and SO) under the supervision of the steering group. The systematic search strategy was based on the following PICO (Population, Intervention, Comparator, Outcome)-adapted components: body parts, ultrasound, and scanning procedures. Online Supplementary Table 1 shows the synonyms used for each component. The search excluded animal studies, prenatal or postpartum US and surgery-related studies. Due to the great number of synonyms for body parts, we divided the review into two separate searches, one for MS structures, mainly related to joints, and a second one for non-MS structures, i.e. salivary glands, vessels and nerves.

The literature search was performed in Medline and Embase from their inception to the 1st of May 2015. Online Supplementary Table 2 shows the literature search strategy. References identified were imported into a bibliographic manager (EndNote(R)) and duplicates were removed. The remaining articles were assessed by title and abstract to identify eligible studies, i.e. those in which a description of scanning procedures of RMD related body parts were detailed. Only articles in English, German, French, Spanish and Italian were retained.

Data about the examined area, patient position, probe placement, scanning method, landmarks and pathologies were extracted from each article using a predefined data collection form. The results were provided to the full expert panel. The review did not include an evaluation for the risk of bias of the individual studies as the objective was to collect narrative procedures and not to answer a specific research question.

Delphi survey

The steering group developed an English-language survey that included six MS anatomic areas, i.e. shoulder, elbow, wrist and hand, hip, knee, and ankle and foot, and three non-MS organs/systems, i.e. peripheral nerves, salivary glands, large vessels. For each anatomic area/organ/system, a variable number of structures and pathologies (1-14 per structure) derived from the literature review were included. These included 39 structures for the shoulder, 36 for the elbow, 15 for the wrist, 17 for the hand, 28 for the hip, 41 for the knee, 64 for the ankle, 12 for the foot, 20 for peripheral nerves, 3 for salivary glands, and 18 for large vessels.

The questionnaire consisted of 9 tables (i.e. one table for each MS anatomic area/non-MS organ/system) with the recipients required to respond to four statements. The first two statements addressed whether the respondent actually assessed the structure ("Examination included in my practice") and his or her satisfaction with that visualization ("Quality of visualization of the structure"). The second two statements evaluated the respondents opinion as to whether that visualization enabled them to detect pathology ("Capability of evaluation

of the abnormality") and if it was relevant to their practice ("Relevance for rheumatology clinical practice").

The questionnaire was sent by e-mail to a broad group of rheumatologists and radiologists expert in MSUS in RMD. An explanation of the purpose of the survey was provided with the questionnaire. The Delphi participants included rheumatologists with more than 5 years of experience in MSUS and EULAR level 2 in MSUS competency or European Federation of Societies for Ultrasound in Medicine or Biology (EFSUMB) level 3 in MSUS competency or Faculty members of international MSUS courses organized by other societies and radiologists from a list provided by the ESSR based on their proven expertise in practice, teaching and research in MSUS.

The surveyed experts were asked to rate each statement on a 1-5 Likert scale as follows: 1=never and 5=always for the statement "Examination included in my practice"; 1=very poor and 5= excellent for the statements "Quality of visualization of the structure" and "Capability of evaluation of the abnormality"; and 1=minimal and 5= maximal for the statement "Relevance for rheumatology clinical practice". Those structures that scored both ≥ 3 for the statement "Examination included in my practice" and ≥ 4 for the statement "Quality of visualisation of the structure" by ≥ 70% of the respondents were selected for the subsequent steps. Those pathologies that scored ≥ 4 by ≥ 70% of the respondents for both statements "Capability of evaluation of the abnormality" and "Relevance for rheumatology clinical practice" were selected.

Nominal group technique
A subgroup of the task force panel composed of 14 rheumatologists (including those from the steering group), 3 radiologists, the methodologist, the patient and the two HP attended a two-day meeting in Madrid (Spain). The tables with the selected anatomic structures obtained from the Delphi survey and their US scanning method extracted from the literature review were sent by e-mail to these panelists three weeks before the nominal meeting.

During the meeting, participants worked in small groups to define optimal US scanning procedures regarding patient position, probe placement, scanning method and bony landmarks of the selected structures. These experts scanned healthy models using seven top-end US machines (LOGIQ E9 XDclear, GE Medical Systems Ultrasound and Primary Care Diagnostics, LLC, Wauwatosa, WI, USA) equipped with a multifrequency linear matrix array transducer (ML6-15 MHz) used for shoulder, elbow, wrist, hip, knee, ankle, salivary glands, vessels, and peripheral nerves in deep areas and a multifrequency linear hockey-stick transducer (L8-18 MHz) used for hand, feet and vessels and peripheral nerves in superficial areas. Grey-scale and power/colour Doppler settings were optimized for the different assessed joints. The results of the small work groups were then presented to the group as a whole to achieve consensus regarding the production of the final images.

Production of the US scanning App
The final phase of the nominal group meeting consisted of photographing of the US scanning procedures and the capture of static US images and videos for the online US scanning App.

Patient and HP perspective
The patient representative was asked to participate in the small and large group discussions as well as the scanning and recording sessions and to provide her feedback from the patient's perspective in order to obtain optimal imaging with the least discomfort to the patient. The HP were also instructed to give their opinion on the procedures from their unique perspective.

Statistical analysis

Simple descriptive and summary statistics were calculated from the responses to the survey.

Results

Scoping review
The literature search resulted in 7706 articles, of which 176 articles were selected for detailed review and 47 articles provided the most relevant information (20-66). Online Supplementary Figure 1 shows the study flow-chart for the article selection. The main reason for article exclusion after full-text review was the lack of standardized examination description. The resulting tables with the description of the scanning procedures as they were presented to the panel are available upon request.

Delphi survey
A total of 227 international MSUS experts who fulfilled the selection criteria were identified and were sent the Delphi survey. One hundred thirteen experts (107 rheumatologists, 6 radiologists; 86 European, 27 non-European) responded the survey (response rate 49.8%).

General recommended procedures for MSUS assessment in RMD
MSUS is a real-time, highly dynamic imaging technique. The "dynamic" nature refers not only to the ability to visualize the structure of interest while it is in motion or being actively stressed but also to the necessity of moving the probe, and, therefore, the US beam, by means of translation, angulation and rotation to enhance and augment the acquired image in order to obtain the highest quality image possible. The ability to produce optimal US images, either as a single image or as a cine clip, is dependent on the examiner's anatomic knowledge, his or her technical proficiency and the quality and correct adjustment of the settings of the equipment. General recommended procedures for MSUS in RMD are presented in Table 1 and online supplementary text. HP and a patient perspective are shown in online supplementary text and online supplementary tables 1 and 2.

Table 1. General recommended procedures for MSUS assessment in RMD

1) MSUS includes two principal modes: B-mode (or grey-scale) that provides us with morphological information of the anatomic structures and Doppler mode (colour Doppler or power Doppler) that allows us to evaluate vessels.
2) MSUS should be performed with high-resolution linear transducers (i.e. probes) with frequencies between 6-14 MHz for deep/intermediate areas to 15-22 MHz for superficial areas.
3) Tissue harmonic imaging, spatial compound imaging, extended field of view (panoramic) and virtual convex imaging are some of the software capabilities that may be useful in MSUS.
4) When scanning a joint, the probe should be oriented perpendicularly to the bony cortical surface (bony acoustic landmark) so that the cortical margin appears bright, sharp and hyperechoic
5) A dynamic scanning technique, using slight movements of the probe from side-to-side, back-to-front or rotation should be carried out in order to allow the best visualization of the structure(s) of interest.
6) It is also important to evaluate MS structures as they move smoothly either actively or passively

7) To avoid anisotropy (i.e. hypoechoic/anechoic appearance of a normally hyperechoic structure that mainly affects tendons) and the common pitfalls that accompany it, it is necessary to continuously adjust the probe to maintain the beam perpendicular to the tendon fibres especially in insertional regions.

8) When the long axis of the structure of interest corresponds to the cranial-caudal orientation of the anatomic position, the most proximal aspect of the structure is usually placed on the left-hand side of the screen. However, other options are acceptable as long as a consistent probe orientation is maintained. Short axis orientation on the screen is at the preference of the examiner.

9) Probe compression can be helpful in distinguishing a compressible liquid collection from a non-compressible solid. Little or no compression is important when performing Doppler examination to avoid cessation of flow in small vessels.

10) A generous amount of gel should be used for superficial structures especially when little or no pressure is indicated.

11) The machine setting for B-mode and Doppler mode should be properly adjusted to optimize the US images acquisition process.

Standardized procedures for MSUS assessment in RMD
Structures from nine anatomic areas/organ/system (i.e. shoulder, elbow, wrist and hand, hip, knee, and ankle and foot, peripheral nerves, salivary glands, and large vessels) were selected for MSUS in RMD as well as detailed scanning procedures (i.e. patient position, probe placement, scanning method and bony/other landmarks) shown in Online Supplementary Tables 3-11 and in the the EULAR Ultrasound Scanning App (www.eular.org; http://ultrasound.eular.org/).

Abnormalities evaluable by MSUS in RMD and prioritization for rheumatology
The US-evaluable and relevant for rheumatology abnormalities present in RMD for each anatomic structure are displayed in Online Supplementary Tables 12-21. Although the detection of features of Sjögren syndrome in salivary glands was considered highly relevant for > 80% of the participants in the survey, less than 70% of them considered US highly capable to evaluate this pathology.

US scanning App
The final product of the task force was the elaboration of the EULAR Ultrasound Scanning App which is a comprehensive electronic illustrated manual of image acquisition in rheumatologic MSUS. This tool displays the procedures (i.e. patient position, probe placement, scanning method and ultrasound images and videos) for MSUS assessment of the principal joint areas and non-articular anatomic regions of importance in RMD (www.eular.org; http://ultrasound.eular.org/).

Discussion
The increasing utility of MSUS in rheumatology has led to a dramatic increase in the demand for education in the appropriate use of this imaging modality among rheumatologists worldwide. The rheumatologist as ultrasonographer has the unique advantage of correlating the clinical picture with the imaging in a more advanced way and we have not made enough of the advantages of this heretofore. As all imaging assessments, MSUS is highly dependent of the operator expertise mainly because of the intrinsic real time nature of image acquisition, standardization of the scanning procedures is an important requisite for the skilled and safe use of this technique in clinical practice and research.

Fifteen years after the publication of the Guidelines for Musculoskeletal Ultrasound in Rheumatology (9), a thorough revision of the procedures for US imaging in rheumatologic practise with the inclusion of new anatomic regions relevant to RMD was performed by an international panel of experts in MSUS. The principal aim was to enhance the standardization and improve the quality of the scanning of anatomic structures evaluable by US and relevant for rheumatology through a consensus process among an international expert panel of rheumatologists and radiologists who practice, teach and pursue research in MSUS in RMD. In addition, the task force has created an illustrated online App of these techniques as a useful educational tool accessible to all with interest in incorporating MSUS into their practice. It is the goal of this panel and its sponsor, EULAR, that this application will become a primary teaching and reference resource for rheumatologists, radiologists, non-medical HP (69) and other specialties involved in the management of RMD worldwide, and as a result, enhance the standardization of the ultrasound assessment.

To achieve this, the pathologies evaluable by MSUS and relevant for rheumatology were elucidated through the Delphi survey process. The objective of our task was to collect expert opinion on the technical capability of US to assess abnormalities in RMD and the degree of priority of US assessment of these abnormalities in their clinical practice and not to establish evidence-based indications for MSUS as some scientific societies have done and published (14-19). We selected anatomic structures that scored > 3 by the majority of the respondents for the first statement regarding the inclusion of the structures in their practice to ensure that there was sufficient experience with the visualization of that structure which, in turn, enabled us to consistently score the second statement as to the respondents' perception of the quality of that visualization. The acceptance value for this criterion was purposefully set lower than the other criteria in order to capture new structures that may not have been considered in the initial criteria but now with advances in the overall knowledge of rheumatic diseases, along with advances in instrumentation and the ultrasound skill-set including anatomic knowledge, are now becoming part of MSUS in RMD. The remainder of the statements relating to the quality of imaging, the capability to evaluate abnormality and relevance to clinical practice required a higher score of > 4 by 70% of the respondents.

Our results indicated an advanced level of US practise among our respondents and a great interest in a wide spectrum of MSUS pathologies detectable in RMD. The use of MSUS for evaluation of the non-MS structures, i.e. the peripheral nerves, salivary glands and large vessels, was relatively limited which we felt could be related either to a general lack of experience along the respondents or, possibly, a lack of evidence validating their use. It was the opinion of the panel that standardization of the scanning procedures for these structures would further facilitate their clinical application in MSUS practice and encourage further research into this group of structures as they relate to RMD.

Some limitations of our project should be mentioned. The number of radiologists who participated in the Delphi survey and consensus meeting was small compared to that of rheumatologists. This can be explained by the dramatic expansion and implementation of MSUS among the rheumatologists, who are highly motivated to collaborate in the enhancement of MSUS use in practice and research. In addition, for logistic reasons, only a subgroup of the experts involved in the Delphi process were able to participate in the nominal group meeting where the detailed scanning method was agreed upon and established. However, we believe that this subgroup was sufficiently representative of the entire community of MSUS experts.

Finally, the addition of the patient and the HP to the panel has provided a unique perspective providing technical and practical advice in improving the US experience for not only the patient but all participants.

In conclusion, we expect this enhanced consensus-based comprehensive and practical framework for MSUS procedures in rheumatology to be a valuable educational tool and provide a standard reference for MSUS practice and research in RMD. EULAR and the European Federation of Societies for Ultrasound in Medicine and Biology (EFSUMB) offer a structured curriculum to be followed to achieve competency in MSUS in rheumatology.

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