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The reliability of musculoskeletal ultrasound in the detection of cartilage abnormalities at the metacarpo-phalangeal joints

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SUMMARY

Objective: To assess the reliability of ultrasound (US) in detecting cartilage abnormalities at the metacarpo-phalangeal (MCP) joints in people with cartilage pathology.
Methods: Nine expert ultrasonographers initially achieved consensus on definitions and scanning protocols. They then examined the second to fifth MCP joints of the dominant hand of eight people with hand osteoarthritis (OA). US examinations were conducted in two rounds, with independent blinded evaluations of cartilage lesions. Global cartilage abnormalities were assessed by applying a dichotomous (presence/absence) score; in addition, the following lesions were evaluated using the same scoring system: loss of anechoic structure and/or thinning of the cartilage layer, and irregularities and/or loss of sharpness of at least one cartilage margin. Reliability was assessed using kappa (k) coefficients.
Results: Thirty-two joints were examined. Intra-observer k values ranged from 0.52 to 1 for global cartilage abnormalities; k values ranged from 0.54 to 0.94 for loss of anechoic structure and/or thinning of cartilage layer and from 0.59 to 1 for irregularities and/or loss of sharpness of at least one cartilage margin. Values of k for inter-observer reliability were 0.80 for global cartilage abnormalities, 0.62 for loss of anechoic structure and/or thinning of cartilage layer, and 0.39 for irregularities and/or loss of sharpness of at least one cartilage margin.
Conclusion: US is a reliable imaging modality for the detection of cartilage abnormalities in patients with cartilage pathology in the MCP joints. The analysis of specific cartilage measures showed more variable results that may be improved by modifying definitions and further standardization of US techniques.

Introduction

Osteoarthritis (OA) is the most common rheumatic disease, affecting most peripheral joints[1]. Pathologically the OA process involves multiple joint tissues, with predominant involvement of the hyaline cartilage, showing focal and diffuse degeneration with areas of progressive cartilage loss[1,2]. The hand is commonly involved representing a frequent reason for consultations in primary care.

Radiography is the traditional tool for imaging hand OA, and is valuable for detecting structural joint changes; however it is not able to directly visualize cartilage and employs a surrogate measure, joint space narrowing. Thus, the availability of imaging tools to directly assess cartilage would be of great value, especially in the early diagnosis of OA, where there may be paucity of symptoms and few clinical findings.

Musculoskeletal ultrasound (US) is a valuable imaging modality for detecting and quantifying a range of pathologies occurring in

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hand joints in inflammatory arthritis and in OA[3–5]. It has been demonstrated to be able to show early and late findings related to inflammation and structural damage, including cartilage lesions[3,4,6–9]. Particularly, the frequent involvement of MCP joints in OA has been previously reported by Keen *et al.* who demonstrated that those joints can be a target area in hand OA[4].

Importantly US can directly image certain components of articular cartilage. Normal hyaline cartilage is imaged by US as a homogeneously anechoic layer lining the bony cortex and having a superficial and deep margins that characteristically appear thin, sharp, continuous and regularly hyperechoic. In OA, a wide set of abnormalities are visualized, with evidence of loss of the anechoic texture, irregularities of the margins and progressive thinning. However, for the poor contrast between hyaline cartilage and synovial fluid that are both anechoic, it can be sometimes difficult to assess small focal defects of the articular cartilage by using US. In addition, while there is evidence in the literature concerning the ability of US to evaluate cartilage involvement in large joints[1,9–14] there is a paucity of data about cartilage assessment at hand joints[8,9,15]. Moreover, there is still the common perception in the medical community that US is a highly operator dependent technique.

The aim of the present study was to assess the intra- and inter-observer reliability of US in detecting cartilage abnormalities at metacarpo-phalangeal (MCP) joints level in patients with cartilage pathology.

Patients and methods

Patients

A total of eight patients, consecutively recruited from the outpatient Rheumatology Unit of Sapienza Università di Roma, were included in the study and underwent MCP joints US examination of the dominant hand. All patients met American College of Rheumatology (ACR) criteria for hand OA[16]. The presence of any other rheumatic diseases was an exclusion criterion from the study. Ethical committee approval was obtained and all patients gave their written informed consent.

US examinations

Nine rheumatologists from four countries, all expert in musculoskeletal US, participated in the study. They were members of the OMERACT US group and the OMERACT/OARSI US task force. Previously, a multistage process consisting of a number of different steps was undertaken. This started with a systematic review that was provided to the group prior to a Delphi exercise[17]. Subsequently the group participated in a Delphi exercise to reach consensus on which abnormalities and definitions they would recommend for testing the reliability of US in hand OA (Table I). Then, based on the suggestion to differentiate findings studying inflammation and those assessing structural damage, they firstly tested definitions for structural abnormalities in a patient-based exercise and an image-based reliability exercise. Hence, focussing particularly on cartilage lesions, they met 2 consecutive days, at first, to discuss the US protocol and scanning technique of the hyaline cartilage of the metacarpal heads and, subsequently, to perform the US intra- inter-observer reliability exercises. Indeed, previously to start the patients' sonographic examinations, the US methodology was clarified among ultrasonographers and a consensus was obtained both on scanning protocol and image interpretation of normal and pathological US findings; for this purpose, a training session on static images that had been previously collected by the same experts and randomly presented by the local organizer (AI) was performed on the same meeting.

Table I
Results of the Delphi exercise

High–good agreement (>80%) for including:

- Cartilage (90%)
- Cortical bone: Erosions (85%), Osteophytes (100%), Cortical irregularities (85%)
- Synovial membrane and synovial fluid (80%)

High–good agreement (>80%) for including:

- All those structures (80%)

High–good agreement (>80%) for including:

- Definitions (Cartilage abnormalities; Cortical bone lesions; Synovitis)

Poor–moderate agreement (<80%) for including:

- Ligaments and their changes (55%)

Suggestion to differentiate:

- Findings studying inflammation and those assessing structural damage

Patients were located in a confortable examining room with their dominant hand lying on an examination table. The single seats were placed at a distance that permitted a blinded and separate evaluation by the nine sonographers, each of whom was seated in front of a single patient. By keeping the joints in maximal flexion (more than 45°), from second to fifth MCP joints of the dominant hand were examined twice in two rounds, with independent evaluations of the various cartilage lesions. The time frame between the two rounds was 6 h. Global cartilage abnormalities at metacarpal heads were searched for, at first, by applying a dichotomous (presence/absence) score. In addition, during the same scanning session and using the same scoring system, the following basic lesions were evaluated: loss of anechoic structure and/or thinning of cartilage layer, and irregularities and/or loss of sharpness of at least one cartilage margin (Fig. 1). All joints were examined with a longitudinal dorsal scan, performed at the level of the median portion of the MCP joints, according with the technical observations that were agreed during the consensus meeting (Fig. 2). Particular attention was paid to keeping the probe perpendicular to the cartilage surface, which was obtained by performing slight sweeping movements with the transducer over the region of interest. All US examinations were performed by applying abundant amounts of gel to the skin to provide an appropriate acoustic interface.

Equipment

Eight identical MyLab 70 X-Vision Gold machines (ESAOTE Biomedica, Genoa, Italy), equipped with a multi-frequency (6–18 MHz) linear probe operating at a frequency of 18 MHz, were used. Previously to start the examination procedure, the same B-mode setting was recorded for all machines and was not modified during the study, including the positioning of the focus at the level of the region of interest and the application of 50% gain.

Statistical analysis

Intra-observer reliability and inter-observer reliability were assessed by using standard Cohen's kappa (k) coefficients[18]. While intra-observer coefficients were evaluated on pairs of measures performed by the same sonographer at each site, calculation of inter-observer coefficient was exclusively based on the first measure of those pairs. Global inter-observer reliability was

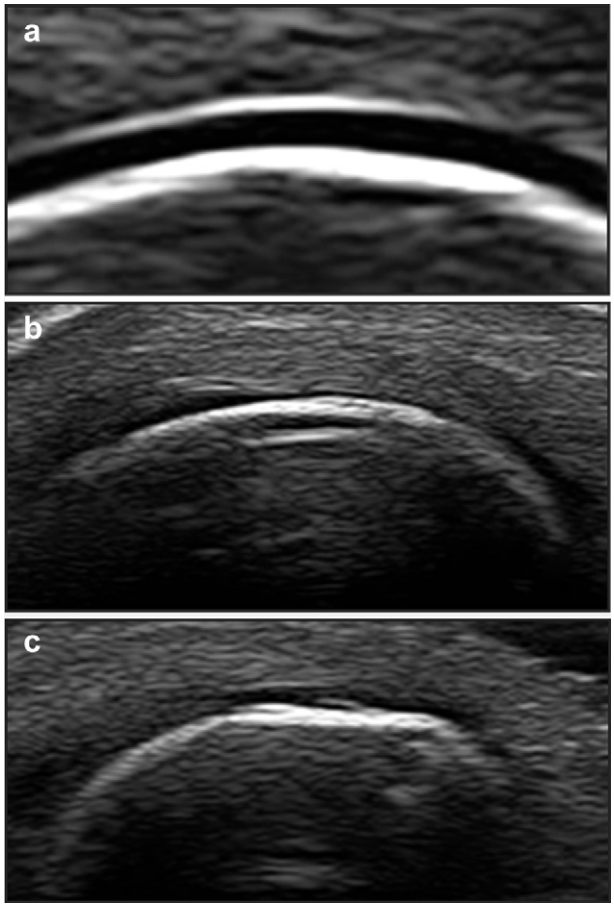

Fig. 1. Longitudinal dorsal scan of the II metacarpo-phalangeal joint. a: Normal cartilage. b: Thinning of cartilage layer. c: Irregularities and loss of sharpness of superficial cartilage margin.

obtained by calculating the mean k for all $n(n-1)/2$ pairs, n being the number of sonographers (i.e., Light's k)[19,20]. k coefficients were interpreted according to Landis and Koch (_0: poor; 0.01–0.20: slight; 0.21–0.40: fair; 0.41–0.60: moderate; 0.61–0.80: substantial; 0.81–1.00: almost perfect)[21].

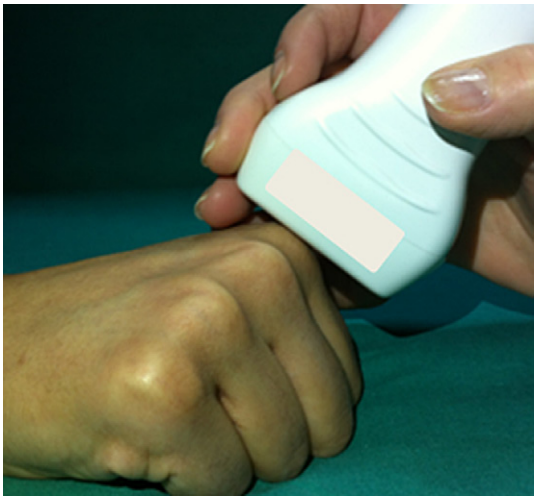

Fig. 2. Scanning technique: longitudinal dorsal scan, performed at the level of the median portion of the II MCP joint.

Results

The main clinical and demographic characteristics of patients included in the study are reported in Table II. They were six women and two men with a median age of 65 years and median disease duration of 38 months. No clinical OA in MCP joints was present. Thirty-two MCP joints were evaluated by all investigators. The scanning time was 15 min per patient.

The prevalence of US-detected cartilage abnormalities is reported in Table III. A variable prevalence of global cartilage abnormalities (51.6–75), loss of anechoic structure and/or thinning of cartilage layer (37.5–92.2), and irregularities and/or loss of sharpness of at least one cartilage margin (34.4–62.5) was found.

The observed agreement and the kappa coefficient concerning intra-observer reliability exercise are shown in Table III; inter-observer reliability results are listed in Table IV.

The observed intra-observer agreement with regard to the detection of global cartilage abnormalities ranged from 0.81 to 1. Similar results were obtained for the basic cartilaginous lesions with values ranging from 0.81 to 0.97 for loss of anechoic structure/thinning of cartilage layer, and from 0.81 to 1 for irregularities/loss of sharpness of cartilage margins.

The observed agreement between ultrasonographers concerning the presence/absence of global cartilage abnormalities was 0.9, for loss of anechoic structure/thinning of cartilage layer it was 0.81, and for irregularities/loss of sharpness of cartilage margins it was 0.72.

From moderate to excellent intra-observer reproducibility ($k = 0.52–1$) was found for global cartilage abnormalities. The analysis of single elementary components of cartilage involvement demonstrated variable intra-observer reliability, with results varying from moderate to very good level of agreement ($k = 0.54–0.94$) for loss of anechoic structure/thinning of cartilage layer and ranging from moderate to excellent level of agreement ($k = 0.59–1$) for irregularities/loss of sharpness of cartilage margins.

The evaluation of inter-observer reliability demonstrated substantial level of agreement ($k = 0.80$) for global cartilage abnormalities. Similar findings were demonstrated for loss of anechoic structure and/or thinning of cartilage layer with a good agreement level ($k = 0.62$) among the ultrasonographers. However, only fair inter-observer reproducibility ($k = 0.39$) concerning the detection of irregularities and/or loss of sharpness of at least one cartilage margin was obtained.

Discussion

As far as we know, this represents the first study focussing on the analysis of intra- and inter-observer reliability of US in demonstrating qualitative cartilage abnormalities of MCP joints in people with cartilage pathology.

As previously reported, MCP joints represent a target area in hand OA, as well as inter-phalangeal joints that are also typically involved[4]. However, for the frequent presence of large osteophytes

Table II
Patients clinical and demographic characteristics

Number of patients	8
Gender (female/male)	6/2
Age years, median (min-max)	65 (60–78)
Disease duration, months, median (min-max)	38 (9–52)
Therapy (N/%)	
Analgesic drugs	4 (50%)
NSAIDs	3 (37.5%)
Chondroprotective drugs	5 (62.5%)

Table III
Results of intra-observer reliability of US in detecting global cartilage abnormalities and elementary components in metacarpo-phalangeal joints of patients with hand OA

	Reliability
Global cartilage abnormalities	
Prevalence (range of %)*	51.6–75
Observed agreement (range)†	0.81–1
Kappa (range)‡	0.52–1
Loss of anechoic structure and/or thinning of cartilage layer	
Prevalence (range of %)*	37.5–92.2
Observed agreement (range)†	0.81–0.97
Kappa (range)‡	0.54–0.94
Irregularities and/or loss of sharpness of at least one cartilage margin	
Prevalence (range of %)*	34.4–62.5
Observed agreement (range)†	0.81–1
Kappa (range)‡	0.59–1

* Range across sonographers of mean prevalence of two paired measures per sonographer; the denominator used is the number of examined sites.
† Range of values across participating sonographers.
‡ Kappa was set to 1, although not estimable when observed agreement was perfect and all observations were in only 1 cell of the contingency table. One kappa value was null due to a void column in the two tables so we gave the second worst result.

that limit the width of the acoustic windows, US assessment of hyaline cartilage at the level of proximal-interphalangeal and distal-interphalangeal joints may be difficult and limited only to some portions of it[22,23].

Before our study, only one recent research has examined cartilage involvement in patients with OA by measuring the maximal distance between cartilage margins in proximal interphalangeal and MCP joints[9]. However, due to improvement in technology, new US equipment is able to depict the cartilage structure with much improved resolution[24]. This has recently led to the demonstration of a wide range of qualitative abnormalities correlated to cartilage damage and has been previously underlined also by Filippucci and colleagues who analyzed cartilage involvement at MCP joints level in rheumatoid arthritis and observed that the excellent resolution of current high-quality US equipment allows a qualitative assessment of cartilage damage[8]. Therefore this approach seems to be appropriate in offering an extensive and more sensitive detection of cartilaginous involvement since early disease, respect to the measurements of the cartilage layer.

This study showed mild variability of intra-observer reproducibility, with agreement ranging from moderate to almost perfect level in the detection of global cartilage abnormalities. Very importantly, the analysis of the same lesion by multiple examiners demonstrated good inter-observer reproducibility. US qualitative analysis of global cartilage abnormalities can, therefore, be considered a reliable method for assessing cartilage damage in hand OA.

In addition, US offers the opportunity to assess certain individual aspects of cartilage pathology that contribute to global cartilage damage. In the current study, there was moderate to excellent intra-observer reproducibility concerning the anechoic structure and/or thinning of cartilage layer. The assessment of this component of cartilage damage by multiple examiners still demonstrated substantial reproducibility. Thus, the evaluation of that particular basic lesion can be considered reliable, particularly when it is assessed by multiple ultrasonographers.

However there were variable results for the qualitative analysis of cartilage' margins involvement. These results were more satisfactory for the intra-observer than for the inter-observer reproducibility. This is probably due to some persistent difficulties in the depiction and interpretation of cartilage' margins irregularities, even after the obtained consensus for scanning technique and image interpretation. These results are in agreement with those obtained by Filippucci and colleagues, who also reported that the most difficult finding to assess by different sonographers was represented by the abnormalities of the cartilage margins[8]. A possible explanation for this aspect can be the lack of contrast between hyaline cartilage and synovial fluid that are both anechoic which can sometimes determine some difficulties in assessing small defects of the articular cartilage. These variegate aspects of US assessment of cartilage abnormalities need further validation data using MRI or histology as reference.

Even considering some variable results, that were mainly obtained by the evaluation of single basic components of cartilage damage, US offered a reliable assessment of global cartilage abnormalities at metacarpal heads level in hand OA.

Our results appear promising and are enhanced by the non-invasiveness and limited expensiveness of US that, in addition, offers the possibility of assessing multiple MCP joints during the same scanning session.

However, a limitation of the present study is represented by the small number of subjects who were assessed, even though a high number of cartilage abnormalities were analyzed. In addition, some technical limitation of US in regard to not being able to assess subchondral bone and to visualize articular surfaces completely for the presence of acoustic barriers represent relevant aspects to be considered when assessing the hyaline cartilage in OA. Thus, despite those limitations, other studies, involving a higher number of patients, are required to further evaluate the US validity in the assessment of cartilage damage in hand OA.

In conclusion, the present study demonstrated that US can be a reliable tool for assessing cartilage abnormalities in MCP joints of patients with cartilage pathology in the MCP joints. The variable results obtained by the sonographic analysis of single basic components may be improved by the application of strict definitions and the standardization of US scanning technique. These results represent a good basis for further sonographic studies on structural damage lesions in hand pathology.

Table IV
Results of inter-observer reliability of US in detecting global cartilage abnormalities and elementary components in metacarpo-phalangeal joints of patients with hand OA

	Reliability
Global cartilage abnormalities	
Observed agreement (mean)*	0.9
Kappa (mean)*	0.80
Loss of anechoic structure and/or thinning of cartilage layer	
Observed agreement (mean)*	0.81
Kappa (mean)*	0.62
Irregularities and/or loss of sharpness of at least one cartilage margin	
Observed agreement (mean)*	0.72
Kappa (mean)*	0.39

* Light's kappa: mean of the $n(n-1)/2$ pairwise agreement coefficients between each pair of the n sonographers.

Authors' contributions

AI has made substantial contributions to conception and design, acquisition of data, analysis and interpretation of data, writing the manuscript; PC has made substantial contributions to analysis and interpretation of data and drafting the manuscript; PA has made substantial contributions to interpretation of data and drafting the manuscript; IM has made substantial contributions to acquisition of data and drafting the manuscript; GAWB has made substantial contributions to interpretation of data and drafting the manuscript; ICV has made substantial contributions to interpretation of data and drafting the manuscript; EF has made substantial contributions

to interpretation of data and drafting the manuscript; FG has made substantial contributions to interpretation of data and drafting the manuscript; DL has made substantial contributions to acquisition of data and drafting the manuscript; EN has made substantial contributions to acquisition of data and drafting the manuscript; MAD has made substantial contributions to conception and design, interpretation of data and drafting the manuscript.

All authors read and approved the final manuscript.

Conflict of interest

The authors have no conflict of interest. The authors declare that there is no financial support or other benefits from commercial sources for the work reported on in the manuscript, or any other financial interests that any of the authors may have, which could create a potential conflict of interest or the appearance of a conflict of interest with regard to the work.

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