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Ultrasonography of the metacarpophalangeal joints in healthy subjects using an 18 MHz transducer.

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Abstract

Aim: To evaluate the metacarpophalangeal (MCP) joints (MCP2 and 5) in healthy subjects by ultrasonography (US) using a high frequency transducer (18 MHz) and to verify the interobserver agreement. **Material and methods:** We enrolled 50 healthy volunteers (37 women, age between 30-58 years, mean age 41.7 years, divided into 3 groups according to age: 30-39, 40-49, and 50-58 years). The subjects were successively evaluated by 4 rheumatologists: 2 experienced (team A) and 2 beginners (team B) in US. Seven dorsal and palmar longitudinal scanning positions and a supplementary scan for MCP cartilage were performed. The bone surface (erosions, osteophytes), the intra-articular content (synovial thickening and vascularization, 4 grade scale), and the aspect of the metacarpal head cartilage were analyzed. The anterior palmar recess was measured. The time for examination was recorded. **Results:** Erosions were detected in 7% of joints by team A and 2% by team B ($p<0.05$, kappa agreement 0.567) in subjects over 40 years. The agreement by team A in the detection of the erosions was very good (kappa value 0.83). A moderate positive correlation was obtained between the presence of erosions and age ($r= 0.401$, $p=0.004$). Osteophytes were identified only on the dorsal scan in subjects over 50 years (in 3.5% of joints team A, 1.5% team B, $p>0.05$, kappa value 0.421). No grade 1 synovitis was observed by team A but 4 joints with grade 1 synovitis were identified by team B ($p<0.05$) from the dorsal scan. The dimensions of the palmar recess had large distribution (MCP 2 between 0.55-1.3 mm; MCP 5 between 0.6-1.2 mm). No statistical significant differences were obtained when comparing the dimensions of the two hands or the values obtained in age-groups (all $p>0.05$). No statistical significant correlations were obtained between the dimensions of palmar recess and the body mass index or dominant hand (all $p>0.05$). No pathological findings were found in the examination of the metacarpal head cartilage. Power Doppler investigation found the presence of grade 1 signal in 2.5% joints by team A and 1.5% by team B ($p>0.05$) only in the dorsal scans. The mean time for examination was 7.8±1.74 min in team A and 13.78±2.96 min in team B ($p<0.05$). **Conclusions:** In healthy subjects pathological findings are occasionally encountered, especially erosions and osteophytes. Using an 18 MHz transducer the aspect of grade 1 synovitis was not encountered in healthy non-inflammatory MCP joints. There is a permanent need for standardized training and examination in musculoskeletal US.

Keywords: ultrasonography, high frequency transducer, metacarpophalangeal joints, healthy subjects

Ultrasonography (US) has become in the latter years an essential tool in rheumatological practice for diagnosis, monitoring, and assessment of remission in all pathological situations that involve the joints and/or periarticular structures [1]. Due to the increased quality of the US machines and, more important, of the higher frequency of the transducers used for the evaluation of the small joints, it is now possible to identify lesions/structures smaller than 1 mm. It is well known and accepted that US is more sensitive and reliable compared with clinical examination, not only for the small joints but also for the large joints [2-4]. That is why it is mandatory to clearly delimitate the normal from pathologic US findings, to

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recognize anatomical variants, to identify physiological situations, and to understand the anatomy and histology of the joints.

Being considered an operator-dependent tool, standardization of the US was a matter of debate over the years. In 2005 OMERACT (Outcome Measures in Rheumatoid Arthritis Clinical Trials) group published an expert consensus on US definitions for pathological findings in inflammatory rheumatologic diseases [5]. These definitions are considered to form a standardized nomenclature.

Grey-scale US is well suited for synovium visualization. The scoring systems developed for grading the synovial hypertrophy generally used semiquantitative criteria [6-8], being considered to be the standard approach. The Szkudlarek et al scoring system [8] is the most used for scientific and clinical purpose. In all the scoring systems the appreciation of the grade in synovium proliferation (considered to be hypoechoic/anechoic) is made by comparing the level of intra-articular hypoechoic/anechoic structures with the bone landmarks (periarticular bones contour). The difference between the joint fluid and proliferated synovium was taken into consideration in Scheel et al [7] and Szkudlarek et al [8] scores but not in the Backhaus et al [6] score. In fact, in practice this difference is frequently difficult to be assessed; even in the OMERACT definition it is stated that synovial fluid can be hypoechoic or anechoic and synovial hypertrophy hypoechoic (but sometimes isoechoic or hyperechoic). The displacement/compression with the transducer of the intra-articular hypo/anechoic structure may contribute to establish the difference. For these reasons the term of "synovitis" should be reserved only for cases with proved inflammation by using color/power Doppler [9]. The correct interpretation of the grade 1 grey-scale US aspect of the MCP (normal or minimal synovial thickening) is one of the most debated subjects [9-12] concerning US criteria for early inflammatory arthritis.

The anatomy of the metacarpophalangeal (MCP) joint is complex (fig 1). During the time numerous anatomic and imaging (US, magnetic resonance imaging) studies were performed in order to describe all the structures involved in the functionality of this joint [9,13-17] and to explain the localization of the lesions in specific parts of the joints [17]. The US appearance of normal MCP joint is largely influenced by the examination techniques: the perpendicular examination in order to avoid anisotropy, the correct setting for grey-scale of the US machine, the use of high frequency transducers, the quantity of gel (transducer not in contact with the skin), the joint position [18], the quality of images acquisition, etc. The majority of US studies were performed using transducers with frequency lower than 18 MHz. Higher frequencies produce better resolution (but lesser penetration) and investigating this superficial joint with 18 MHz transducer could bring new data regarding its normal appearance.

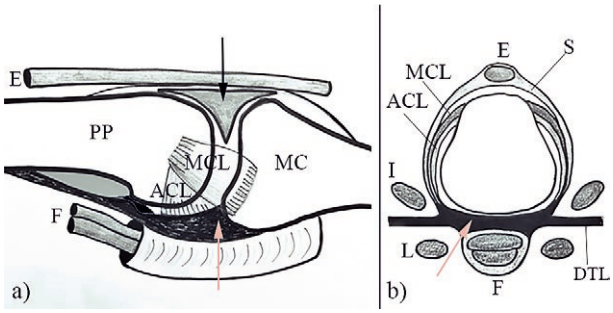

Fig 2. Anatomical drawing of the metacarpophalangeal joint: a) longitudinal aspect; b) transversal aspect at level of the proximal phalanx base. MC – metacarpal bone, PP – proximal phalanx, E – extensor tendon, F – flexor tendons (superficial and profound) in the synovial sheath, L – lumbrical tendon, I – interosseous tendon, S – sagittal band, MCL – main collateral ligament, ACL – accessory collateral ligament, DLT – deep transverse metacarpal ligament, black arrow – dorsal plate, white arrow-palmar (volar) plate.

The **aims** of our study were to evaluate the MCP joints (the second and the fifth MCP) in healthy subjects by US using a high frequency transducer (18 MHz), to establish the frequency and localization of inflammatory (hypertrophied synovium and PD signal) and chronic (erosions and osteophytes) lesions. Also, we intended to measure the required time for evaluation and to verify the interobserver agreement (between experienced and unexperienced examiners) of the findings.

Material and methods

In this prospective study 50 healthy volunteers (37 women, age between 30-58 years, mean age 41.7 years) from the medical staff of our hospital were enrolled. The subjects were enrolled if they have/had no history of pain, arthritis, trauma, or surgery of the fingers joints and if the clinical examinations (performed by an experienced rheumatologist) of the joints was in normal range. Data about age, weight, height, body mass index (BMI) calculated as weight/height^2 and expressed in kg/m^2, physical and sport activities (mild, moderate, intense), and dominant hand were collected. Written, informed consent for participation was obtained from each subject prior to enrolment. The Ethics Committee of the University approved the study protocol.

The subjects were successively evaluated by 4 rheumatologists: 2 with high experience in musculoskeletal US (team A, with 16 and 8 years of experience) and 2 with minimum experience (4 hours training in US ex-

amination of the MCF) in US (team B). All the examinations were blinded concerning the results of the other investigators. The US examinations were performed between 9-11 a.m., after 30 min of relative rest of the hands, without heavy physical work/exercises in the previous 24 hours of examination, and in the same conditions of temperature or light.

A standard scanning protocol was used in every subject. The patient was examined in sitting position, with both hands placed on a table in extension position with the EsaoteMyLab 50 machine using 18 MHz transducer. The larger depth of the machine (2 cm), two focuses, and intermediary time gain control (TGC) were used for grey-scale US. Power Doppler (PD) was assessed using the highest gain level without background noise and pulse repetition frequency of 750 MHz. A sufficient quantity of gel was used in every case (the transducer has not to be in contact with the skin). The scanning protocol was derived from the work of Ellegaard et al [9]. We chose to investigate MCP 2 and 5 as these joints are the most accessible MCF joints for US investigations.

The second and fifth MCPs of both hands were assessed with US in seven dorsal and palmar longitudinal scanning positions and a supplementary scan for MCP cartilage (50 subjects, 200 joints, 1600 US scanning positions) (details for MCF 2 examination in figure 2; for MCF 5 the radial side was inversed by the ulnar side).The following aspects were recorded: *bone surface* (smooth or with irregularities: erosions- step down irregularities visible in two perpendicular plans, osteophytes- step up irregularities) and *the intra-articular content*- synovial thickening (4 grade semiquantitative score [8]) and vascularization (4 grade scale [6]) from all the scanning positions. The anterior palmar recess was measured from scanning position 6, in the point of maximum distension. The aspect of the *metacarpal head cartilage* was verified from the scanning position number 2 with the joint flexed 90° (homogeneity, sharpness of the contour, and the constant width were noted). The necessary *time for examination* was recorded for every subject and every investigator. Al the US images considered representative for every scanning position realized were archived (4 pairs of scanning position). At the end of the study the results obtained were analyzed by team A and B and inconsistencies that occurred within each team of examiners were resolved by consensus after reanalysis of archived images.

Statistical analysis

Data were expressed as percentage and means±standard deviation (SD). The 95% confidence interval for mean was calculated. The chi-squared test or Fisher exact test for comparing categorical data was used. $P \leq 0.05$ was considered statistically significant.

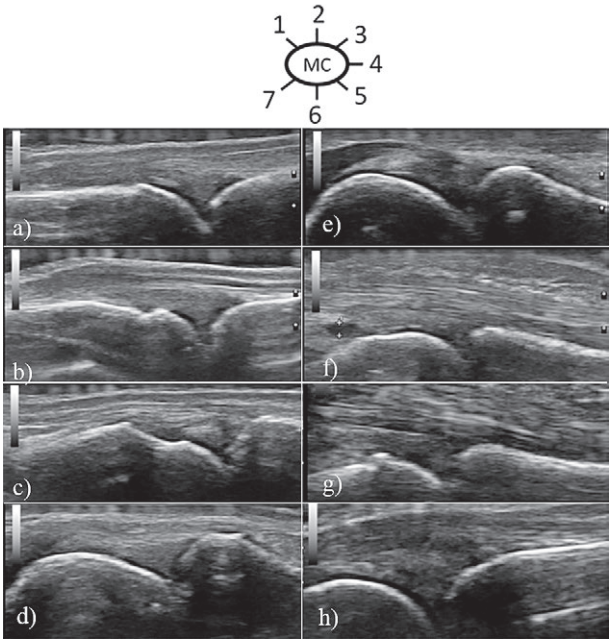

Fig 1. The scanning positions (longitudinal scans) in a second metacarpophalangeal joint (the metacarpal head – MC – is drawn): 1 – dorsal ulnar (a); 2 – dorsal central (b); 3 – dorsal radial (c); 4 – radial (d); 5 – volar radial (e); 6 – volar central (f) – the palmar recess between calipers; 7 – volar ulnar (g); e) the longitudinal scan of the metacarpal cartilage.

Independent sample *t*-test was used to compare quantitative data. Interobserver agreement (concordance) was calculated using the kappa (Cohen's kappa) statistics. Association (linear correlation) between variables was determined by the Pearson correlation coefficient. Data evaluation and statistical analysis were performed with Office Excel SPSS program 19.0 version.

Results

The study subjects were divided into 3 groups according to age (30-39 years, 40-49 years, and 50-58 years). The demographic characteristics of the enrolled subjects are detailed in table I.

The results of the US evaluation of the MCF joints are detailed in table II. Erosions were detected more often by the experienced team ($p<0.05$ referring to the number of joints detected with erosions, $p>0.05$ referring to the number of patients) and moderate agreement (mean kappa agreement 0.567) was obtained. The agreement inside the team A (with high experience in US) in the detection of the erosions was very good (kappa value 0.83). The erosions were found more often on the radial scan of the second MCP (10 erosions,

Table I. Demographic data of the study subjects.

Characteristics/age group	30-39 years	40-49 years	50-58 years
Number of subjects (%)	24 (48%)	14 (28%)	12 (24%)
Female/male	18/6	10/4	9/3
BMI (kg/m2)	24.43	26.97	29.93
Physical activities	moderate	moderate	moderate
Dominant hand: right/left	22/2	13/1	12/0

BMI-body mass index

Table II. The findings of metacarpophalangeal joint US examination.

	Team A		Team B		P value	
	N patients	N joints	N patients	N joints	N patients	N joints
Erosions	9 (18)	14 (7)	4 (8)	4 (2)	0.137	0.016
Osteophytes	4 (8)	7 (3.5)	1 (2)	3 (1.5)	0.168	0.200
Grade 1 synovitis	0	0	4 (8)	7 (3.5)	0.117	0.015
Power Doppler signal	4 (8)	5 (2.5)	3 (6)	3 (1.5)	0.151	0.132
Palmar recess (mm)						
Right MCF 2	0.849±0.144		0.905±0.174		0.026	
Left MCF 2	0.877±0.145		0.844±0.135		0.161	
Right MCF 5	0.849±0.164		0.836±0.191		0.701	
Left MCF 5	0.882±0.205		0.816±0.167		0.032	
Examination time (min)	7.8±1.74		13.78±2.96		<0.001	

Values are expressed as number of patients/joints (%) or mean±SD. N (number) patients= 50; N (number) joints= 200

71.4%), only in subjects over 40 years old, 8 of them being females. Of note, that one subject had 3 erosions (a 58 years-old female) and in 3 subjects we found 2 erosions (all in the third group of age). A moderate positive correlation was obtained between the presence of erosions and age ($r=0.401$, $p=0.004$). Osteophytes were identified in our asymptomatic subjects only on the dorsal scan (scanning position 2), in subjects over 50 years, with a moderate intrerobserver agreement (kappa value 0.421). Concerning the synovitis, team B identified grade 1 synovitis in 2 subjects from the second age-group and in 2 subjects in the third age-group, 3 of them being females. No grade 1 synovitis was observed by team A ($p<0.05$). All cases with grade 1 synovitis aspect were identified from the dorsal scan (scanning position 2) in the first ten subjects examined by the members of team B (beginners). The dimensions of the palmar recess of both MCP joints had a large distribution (MCP 2 between 0.55-1.3 mm; MCP 5 between 0.6-1.2 mm). No statistical significant differences were obtained when comparing the dimensions of the two hands or the values obtained in age-groups (all $p>0.05$). No statistical significant correlations were obtained between the dimensions of palmar recess and height, weight, BMI, or dominant hand (all $p>0.05$). No pathological findings were found in the examination of the metacarpal head cartilage. PD investigation of the MCP joints found the presence of grade 1 signal only in the dorsal scan (scanning position 2).

Discussions

The results of our study showed that in healthy subjects, in MCP 2 and 5, chronic lesions (erosions, osteophytes) occasionally can be found but signs of inflammation, especially acute inflammation (synovitis), are not present.

The problem of the interpretation of grade 1 synovitis (pathological findings or normal aspect) in the finger joints is of real importance. In our study, the experienced team found no joint with the aspect resembling grade 1 synovitis. When reanalyzed, the four cases interpreted as grade 1 synovitis (archived imagined) by team B (beginners), we concluded that the hypoechoic areas represent anisotropy, not synovitis. All 4 scans were from the dorsal part of the MCP (scanning position 2). So, in our opinion the aspect of grade 1 synovitis from the palmar scan can be considered pathologic when an examination is performed using an 18 MHz transducer. From the dorsal scan the interpretations have to be made with caution (especially if no other pathological/clinical findings are present or the experience of the operator is limited), only after the exclusion of the anisotropy artifact.

The dorsal side of the MCP joint is covered by a thicker capsule that forms a dorsal plate [19]. Boutry et al

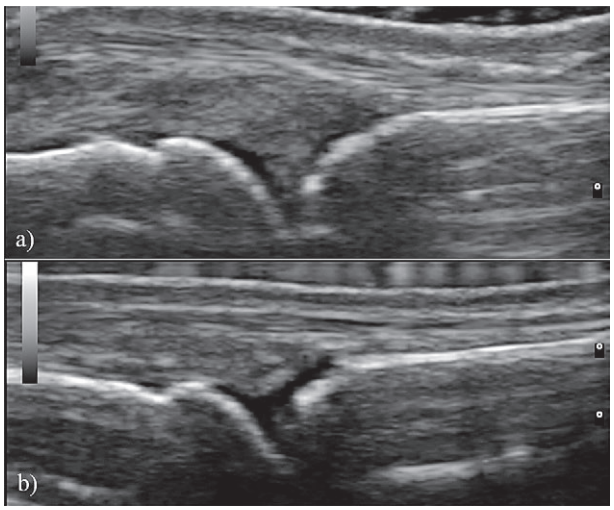

Fig 3. Dorsal longitudinal scan of the metacarpophalangeal joint:the dorsal plate with apex a) pointed and b) truncate.

[14] found in a cadaver study that this structure is a thick yellowish tissue consisting of vascularized connective tissue. The US appearance of the dorsal plate in 30 normal volunteer (visible and analyzable in almost all 120 MCP joints) was of a slightly echoic and homogenous structure between the two bones, firmly attached to the base of the proximal phalanx and more loosely inserted at the metacarpal bone level [14]. This plate is in fact the source of the hypoechoic aspect when the US examination is not perfect perpendicular. Also, Boutry et al [14] specify the possibility that this plate can have the apex pointed (more frequently- 78%) or truncated (we exemplified these aspects in fig 3). Especially in the last case, the "quantity" of hypoechoic content of the joint is increased and can be misinterpreted as "*filling the angle between the periarticular bones, without bulging over the line linking tops of the bones*" as Szkuldarek el al [8] defined grade 1 synovitis.

The dorsal recess is the larger recess of the joint [20,21], with lengths between 6-18 mm [20] and is constantly seen on US examination [14]. The articular cavity is quite spacious in the dorsal part of the joints as the capsule in this region is weaker [20,22]. This means that in extension positions the pressure in the dorsal part of the MCP is not high and, if the US examination is correct, without application of the transducer over the skin, the normal vascularisation of the dorsal plate may be seen in some subjects. For this reason the presence of PD signal without an aspect of grey-scale synovitis should be considered normal, not subclinical synovitis.

On the palmar side, the palmar plate, that consists of tight, inflexible, fibrocartilagenous structure tissue [20,22] with different widths and lengths between fingers [23], is blended with a palmar capsule and in the extension position of the finger, the small vessels are compressed [20,22]. This is probably the explanation why we did not find PD signal on the volar side of MCP. Millot et al [10] found PD signal in 5 of 127 healthy subjects included in study. The authors do not mention the sides were the PD was found but they published an US image with a PD signal from the dorsal side of the joint. Probably the same explanation is valuable for the grade 1 synovitis, due to its incipient pathologic vascularization: in the presence of grade 1synovitis the PD signal was much frequent detected in the dorsal side (28.1%) comparing with palmar side (3.7%) [12]. Also, Witt et al [24] found in patients with newly diagnosed rheumatoid arthritis (RA) more pathologic findings in grey-scale US from the palmar approach and more frequent PD signals from the dorsal approach of the finger joints. In the study realized by Zufferey et al [25] the grade 1 PD signal was found only in 5% of normal volunteers (the authors did not specify the joints where this was found) and they considered to be relevant this grade of PD vascularization for the evaluation of remission in RA patients.

The dimensions of the proximal palmar recess had a large distribution in our study that demonstrates the various anatomical situations. Taking in consideration the anatomical previously discussed aspects, we agree with Ellegaard et al [9] that in the presence of small quantities of synovial fluid or incipient proliferated synovium, these findings can be demonstrated only in the proximal anterior recess, a place where the pressure is low. In this situation, as the finding that synovitis *"with extension to at least one of the bone diaphyses"* [8] confer at least grade 3 of proliferated synovium, the modifications in the palmar proximal recess could be an important factor for the overestimation of the pathological findings and should be taken into consideration. The fact is more important as it was demonstrated that synovitis is more frequently detected on the palmar side compared to the dorsal side [6,12,26,27]. The necessity to define a cutoff of significant synovitis [25] is important for the delimitation of a normal anterior proximal recess from a pathological one.

The presence of erosions in the healthy population was already demonstrated in other published studies. Millot et al [10] found bone erosions in 11% joints (MCP 2-5 and fifth metatarsophalangeal joints) of the 127 healthy subjects studied, the MCP 2 being the second place where the erosions were found (5 cases). No vascularization was detected within these erosions. Szkudlarek et al [11] detected in 20 subjects 10 erosions at MCPs (4.2%) level using MRI (3 mm slice thickness) but no erosions were detected by using US. The authors explained the difference between MRI and US by the visualization by MRI of the subchondral cysts that were

interpreted as erosions. Ejbjerg et al [28] detected low grade erosion-like changes in 2.2% of MCP examined by MRI in 28 normal subjects, especially in the second and the fifth MCP joints. All the lesions were small, without increased signal intensity on postcontrast images.

The presence of osteophytes characterize the hand osteoarthritis [29-31]. We found osteophytes in 7 joints but in the absence of other pathological findings, especially cartilage abnormalities, we could not interpret their presence as belonging to osteoarthritis. Because all the subjects were above 50 years probably these osteophytes were the first imaging findings of a future MCP osteoarthritis. We found no abnormalities of the metacarpal head cartilage in our subjects and this aspect is important as US is considered to be a reliable imaging modality for the detection of cartilage abnormalities [32].

One important target of our study is the comparison between the 2 teams: the experienced and un-experienced teams. The learning curve in musculoskeletal US was found to be an important aspect in the time of gaining skills in beginner ultrasonographers [33-35]. The 2 beginner members of team B rapidly achieved knowledge about MCP examination. The time for an examination was longer compared with the experienced team but with the increasing of the number of subjects examined, this time was improved (for example 20 min the first subject examined and 12 minutes the last one). It has to be underlined that the necessity to archive one representative US image from every scanning position increased the examination time in both teams. So, the need for a good training is mandatory in order to obtained reproducible and clinical relevant data from US examinations.

Our study has a number of limitations. First the small number of subjects enrolled does not permit the drawing of clear conclusions regarding the frequency of the pathological findings in normal subjects. The lack of subjects with intense physical activities in daily life makes it impossible to correlate these findings with mechanical origins of the erosions or osteophytes. Also, we did not compare the US findings with other imaging techniques and with findings in patients with MCP pathology.

In **conclusion**, in healthy subjects, the pathological findings are occasionally encountered, especially with regard to erosions and osteophytes. Using an 18 MHz transducer the aspect of grade 1 synovitis was not encountered in healthy non-inflammatory MCP joints. The moderate agreement between experienced and un-experienced examiners demonstrated the need for an appropriate training for performing musculoskeletal US.

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Conflict of interest: none

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