Inter-observer reliability of high-resolution ultrasonography in the assessment of bone erosions in patients with rheumatoid arthritis: experience of an intensive dedicated training programme

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Abstract

Objective. The present study was aimed at testing the ability of a rheumatologist without experience in ultrasound (US) who attended an intensive 4-week training programme focused on US assessing bone erosions in the hands and feet in patients with RA.

Methods. Twenty patients diagnosed with RA according to the ACR criteria were included in the study. All US examinations were performed bilaterally by two investigators (with different experience in the field of musculoskeletal US) at the following sites: the dorsal, lateral and volar aspect of the second metacarpal, ulnar and fifth metatarsal head; and the dorsal and volar aspect of the third metacarpal and second proximal heads. Each quadrant was scanning in longitudinal and transverse scans for assessing the qualitative, semiquantitative and quantitative US findings indicative of bone erosions according the OMERACT preliminary definition.

Results. Both $\kappa$-values and overall agreement percentages of qualitative and semiquantitative assessments showed moderate to excellent agreement between the two investigators. Similar results were obtained for the quantitative assessment with the concordance correlation coefficient value always significant. The only exception was the volar aspects, in particular those of the fifth metatarsal head.

Conclusion. Our study suggests that after a 4-week dedicated training programme, a rheumatologist without experience in US is able to detect and score bone erosions in the hands and feet of patients with RA.

Key words: Rheumatoid arthritis, High-resolution ultrasonography, Bone erosions, Inter-observer reliability, Training.

Introduction

Bone erosions are the hallmark of joint damage in RA and both their detection and increase in number or size are indicative of a poorer outcome [1–4]. In daily clinical practice, conventional radiography is the standard imaging technique used for detecting and scoring joint damage, in spite of its low sensitivity with respect to CT, MRI and ultrasound (US) [5–14].

The feasibility and construct validity of US in visualizing bone erosions have been known since the early 1990s [13]. Criterion validity of US has been only recently investigated using CT as the gold standard [14]; nevertheless, there is little evidence of its discriminant validity [11, 15]. Since US is considered the most operator-dependent imaging modality, the present study was aimed at testing the ability of a rheumatologist without experience in US who attended an intensive 4-week training programme that focused on assessing bone erosions in hands and feet of RA patients by US and determining the agreement with an experienced sonographer.
Methods

Patients

Twenty consecutive patients (4 males and 16 females) with a diagnosis of RA according to the ACR criteria for RA (formerly the ARA) [16] were included in the present study. Patients <18 years of age or with a history of fracture or surgery of the hand or foot were excluded. All patients were attending the outpatient and inpatient clinics of the Rheumatology Department of the Università Politecnica delle Marche (Ancona, Italy). The median for age and disease duration was 57.5 (95% CI 51.4, 65) and 4.5 (95% CI 3, 9.1), respectively.

Study design

The study was composed of two main steps carried out between April and May of 2008. In the first step, a rheumatologist without any previous experience in US (S.R.) received intensive US training at the Rheumatology Department of Università Politecnica delle Marche, focused on assessment of synovitis and bone erosions in patients with RA. The training programme was run 8 h/day, 5 days a week and lasted 4 weeks. The first week was dedicated to providing the novice with the basic knowledge necessary to perform US scanning of the hands and feet. The following 3 weeks, the novice directly performed the US examinations on RA patients, under direct supervision of experienced sonographers (M.G. and E.F.) who helped to perform the examination correctly. Moreover, the novice had access to a core set of US images displaying the most representative examples of bone erosions (pictorial gallery with all the different scores of bone erosions; Fig. 1) and pitfalls (i.e. osteophytes, sesamoid bones). In the second step, the ability of the novice to detect and score bone erosions was compared with that of a rheumatologist with 6 years of US experience (M.G.). US examinations were performed independently by the sonographers, who were blinded to clinical and radiographic data.

Patients were asked not to talk about their clinical condition with the sonographers. The presence and the size of bone erosions were investigated at the following anatomical sites: the second proximal phalanx head and the second and third metacarpal heads of both hands, the ulnar head bilaterally and the fifth metatarsal heads of both feet. These anatomical sites were chosen because bone erosions in RA occur most frequently at these sites [17]. The study was conducted according to the Declaration of Helsinki and local regulations. The institutional ethics committee (Comitato Etico dell’Azienda Sanitaria Unica Regionale di Ancona) approved the study and informed consent was obtained from all patients.

US examination

US scanning was performed using a MyLab 70 XVG (Esaote Biomedica, Genoa, Italy) equipped with a 6–18 MHz broad-band multifrequency linear transducer (within the focal area the transducer has an axial resolution of 30 μm and a lateral resolution of 60 μm). The US examinations were performed on the anatomical sites previously described. Multiplanar US examination was bilaterally performed in a total of 26 quadrants: the dorsal, lateral and volar aspects of the second metacarpal head, ulnar head and fifth metatarsal head, and the dorsal and volar aspects of the third metacarpal head and

Fig. 1 RA. Second metacarpophalangeal joint on a longitudinal dorsal scan. Grey-scale US images showing bone erosions at the metacarpal head level (+). Maximal diameters of erosion are 0.9 mm (A), 1.9 mm (B), 3.8 mm (C) and 5.8 mm (D), corresponding to Grade 1, Grade 2, Grade 3 and Grade 4, respectively, according to the semiquantitative scoring system proposed by Kane et al. [19]. The white lines indicate where the calliper was located for the measurement of erosions. m: metacarpal bone; p: proximal phalanx.
second proximal phalanx head. Each anatomical area was scanned in both longitudinal and transverse scans from radial to ulnar sides on both volar and dorsal aspects to provide maximum coverage of the anatomical surface area. Figure 2 shows the main scanning planes and the corresponding US images.

Scans of the metacarpal, proximal phalanx and ulnar heads were performed with the patient seated with hands leaning on the examination table (supine for the volar scans and prone for the dorsal scans). The supine position, with knees in flexion and feet leaning on the examination table, and neutral position of the knees were adopted for assessment of the dorsal and volar aspects of the metatarsal heads, respectively.

US images interpretation
For the detection of bone erosions, the OMERACT preliminary definition was adopted: ‘An intra-articular discontinuity of the bone surface which is visible in 2 perpendicular planes’ [18]. The presence or absence of bone erosion was recorded per quadrant and the size of the erosions was estimated by positioning the caliper on the edge of the erosive crater to measure the maximal diameter in both longitudinal and transverse scans. The major value obtained of both scans was considered. The following semiquantitative system (0 = absence of US findings indicative of bone erosion; 1 = very small erosion, < 1 mm; 2 = small erosion, 1–2 mm; 3 = moderate erosion, 2–4 mm; 4 = large erosion, > 4 mm) was used to score the bone erosions [19].

Statistical analysis
Statistical analysis was performed using MedCalc®, version 10.1.2.0 (MedCalc software bvba; Mariakerke, Belgium) for Windows XP (Microsoft Corporation; Redmond, WA, U.S.A.). The inter-observer agreement...
between the two investigators has been calculated in terms of qualitative (presence/absence), semiquantitative (scoring) and quantitative (measurement of size of erosion).

Inter-observer agreements were estimated by ω-statistic [unweighted ω for dichotomous assessment (i.e. presence or absence of erosions) and weighted ω for semiquantitative scoring] and overall agreement (percentage of exact agreement). A ω-value of 0–0.20 was considered poor, 0.21–0.40 fair, 0.41–0.60 moderate, 0.61–0.80 good and 0.81–1.00 excellent [20]. To assess significant differences and agreement between the results of the erosion measurements, we calculated the concordance correlation coefficient (CCC) and 95% CI for the median values. A CCC value >0.8 was considered significant. A Bland and Altman plot was used to show the agreement between the results of the two investigators.

Results

A total of 520 quadrants (120 of second metacarpal heads, 80 of third metacarpal heads, 80 of second proximal phalanx, 120 of ulnar head and 120 of fifth metatarsal heads) of 20 RA patients were scanned by two investigators. Table 1 reports the rates of agreement between the two investigators. Both ω-values and overall agreement percentages of qualitative and semiquantitative assessments showed moderate to excellent agreement between the two investigators. Similar results were obtained for the quantitative assessment with the CCC value always significant; the only exception was the volar aspects of the second and third metacarpal, second proximal phalanx and fifth metatarsal heads. The Bland and Altman plots (Fig. 3) confirmed good agreement between the two investigators.

Figure 4 shows good quality US images depicting bone erosions obtained by the novice. In 15 (75%) of 20 patients, US detected signs indicative of erosions. In this group, a total of 87 erosions were found. The quadrants with the highest number of erosions were the lateral aspect of the second metacarpal head [20 (22.9%) out of 87], the dorsal aspect of the ulnar head [12 (13.7%) out of 87], the lateral aspect of the ulnar head [12 (13.7%) out of 87], the dorsal aspect of the second metacarpal head [11 (13.6%) out of 87] and the lateral aspect of the fifth metatarsal head [11 (13.6%) out of 87], followed by the dorsal aspect of the fifth metatarsal head [6 (6.9%) out of 87], the dorsal aspect of the third metacarpal head [1 (1.1%) out of 87], the dorsal aspect of the second proximal phalanx head [1 (1.1%) out of 87], the dorsal aspect of the third metacarpal head [1 (1.1%) out of 87] and the volar aspect of the fifth metatarsal head [0 (0%) out of 87].

Discussion

In spite of several studies demonstrating that US is more sensitive than conventional radiography in the detection of bone erosions in the small joints of the hands and feet (especially in the early stages) [11, 13, 15, 21–24], only a few investigators have been selected to evaluate the discriminant validity of US in the detection and scoring of bone erosions in patients with RA [11, 15].

<table>
<thead>
<tr>
<th>Quadrants</th>
<th>Presence/absence</th>
<th>Semiquantitative scoring</th>
<th>Quantitative assessment</th>
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<tr>
<td></td>
<td>Unweighted ω-values (S.D.; 95% CI)</td>
<td>Overall agreement, %</td>
<td>Overall agreement, %</td>
</tr>
<tr>
<td>2° Metacarpal head</td>
<td></td>
<td></td>
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<tr>
<td>Dorsal</td>
<td>0.939 (0.060; 0.821, 1.057)</td>
<td>97.5</td>
<td>0.974</td>
</tr>
<tr>
<td>Lateral</td>
<td>0.950 (0.049; 0.853, 1.047)</td>
<td>97.5</td>
<td>0.898</td>
</tr>
<tr>
<td>Volar</td>
<td>0.787 (0.210; 0.375, 1.199)</td>
<td>97.5</td>
<td>0.791</td>
</tr>
<tr>
<td>3° Metacarpal head</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dorsal</td>
<td>0.895 (0.104; 0.691, 1.098)</td>
<td>97.5</td>
<td>0.961</td>
</tr>
<tr>
<td>Volar</td>
<td>0.655 (0.340; 0.312, 1.323)</td>
<td>97.5</td>
<td>0.687</td>
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<tr>
<td>2° Proximal phalanx head</td>
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<tr>
<td>Dorsal</td>
<td>0.844 (0.154; 0.541, 1.146)</td>
<td>97.5</td>
<td>0.902</td>
</tr>
<tr>
<td>Volar</td>
<td>0.665 (0.342; 0.314, 1.423)</td>
<td>97.5</td>
<td>0.655</td>
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<td>Ulnar head</td>
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<tr>
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<td>87.5</td>
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<tr>
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<td>0.655 (0.340; 0.312, 1.323)</td>
<td>97.5</td>
<td>0.658</td>
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<tr>
<td>5° Metatarsal head</td>
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<tr>
<td>Dorsal</td>
<td>0.908 (0.091; 0.731, 1.086)</td>
<td>97.5</td>
<td>0.880</td>
</tr>
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<td>97.5</td>
<td>0.948</td>
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<tr>
<td>Volar</td>
<td>0.481 (0.358; 0.221, 1.182)</td>
<td>95</td>
<td>0.559</td>
</tr>
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</table>
Fig. 3 (A–F) Bland and Altman plots showing the distribution of the erosion measurements in the most frequent quadrants by the two investigators (M.G. and S.R.).

Fig. 4 RA. Grey-scale US features of bone erosions (→) of the second metacarpal head on longitudinal (A) and transverse (B) lateral scans; ulnar head on longitudinal (C) and transverse (D) lateral scans. m: metacarpal bone; p: proximal phalanx; u: ulnar bone; dit: first dorsal interosseous tendon; ecr: extensor carpi ulnaris tendon.
In the last few years, different US training programmes for rheumatologists have been developed and tested [25–28], but there is still no international consensus on which is the best US educational programme. Considering that a large number of rheumatologists are incorporating US into their clinical practices as a valid imaging method for both diagnostic and research purposes, standardized dedicated US programmes have become an urgent issue to address [29]. The present study demonstrates that a rheumatologist without previous experience in US achieved high inter-observer agreement rates for the detection and scoring of bone erosions in patients with RA after intensive US training of 4 weeks.

All the rates of agreement for the qualitative, semiquantitative and quantitative assessments were high for both the novice and the experienced sonographer. The volar aspects, in particular those of the fifth metatarsal head, showed a relatively low level of agreement.

The reasons for the relative disagreement rates include technical, anatomical and pathological causes. For instance, from a technical point of view, a small variation in the movement of the probe from the medial to lateral side can generate a false image of bone interruption, particularly at the anatomical neck of the metacarpal bones (Fig. 5A and B). From an anatomical point of view, the presence of the sesamoid bone on the volar side of the second metacarpal bone (Fig. 5C and D), the thickness of the palmar skin and the deeper location of the joint may impair visualization of the underlying bony cortex. Moreover, limitations in finger extension in patients with long-standing disease impaired the study of the volar aspect of the metacarpal head by reducing the acoustic window. Finally, the presence of pathological osteophytes located on the dorsal or volar side of the heads of bones can generate (according to size) an image that can be wrongly interpreted as bone erosion (Fig. 5E and F).

In our study, the levels of agreement were reported for each basic quadrant, allowing the most difficult ones to be detected and scored. We believe that this is important in order to facilitate training and the development of a standardized teaching programme.

We extended the assessment of US reproducibility of bone erosions to other anatomical sites (such as the ulnar head and fifth metatarsal head) not previously investigated with this aim. Both resulted frequently in bone

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**Fig. 5** Second MCP joint on longitudinal dorsal scan (A). (B) Same subject and same scan with a minimal variation of the position of the probe miming multiples erosions (>) at the anatomical neck of the metacarpal bone level. (C) Second MCP joint on longitudinal (C) and transverse (D) volar scans. Note that the sesamoid bone (>) generates an acoustic shadow that can be interpreted as an erosion. Second MCP joint on longitudinal volar (E) and dorsal (F) scans. The acoustic shadows generated by the osteophytes show erosion-like images (>) at the metacarpal bone level. p: proximal phalanx; m: metacarpal bone; et: extensor digitorium tendon; ft: flexors digitorium tendons.
erosions and showed a high reproducibility. The main limitation of the present study is the small number of patients, which could underestimate the wide erosive spectrum detectable in RA.

Conclusion

The present study suggests that, after 4 weeks of intensive training, a rheumatologist without experience in US is able to detect and score bone erosions in the hands and feet of patients with RA.

Rheumatology key messages

- Dedicated US training enables the detection and scoring of bone erosions in RA.
- The ulnar and fifth metatarsal heads are highly reproducible and frequently involved by bone erosions.
- The erosions at the volar aspects present low reliability due to technical, anatomical and pathological causes.

Disclosure statement: The authors have declared no conflicts of interest.

References

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