Ultrasound imaging for the rheumatologist II. Ultrasonography of the hand and wrist

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ABSTRACT

The hand is one of the anatomical regions most frequently explored by ultrasonography (US) in rheumatology. The last generation US systems equipped with high frequency probes allow for a quick and accurate assessment of even minimal pathological changes in patients with rheumatic conditions affecting the small joints and the soft tissues of the hand and wrist. Several studies have demonstrated the great value of US imaging of the hand and wrist in rheumatology but there are still controversial issues which yet have to be adequately addressed, particularly with regard to US semi-quantitative evaluation of synovitis and bone erosions in patients with chronic arthritis. This paper provides the basic knowledge, reviews the available evidence and discusses the potential of US in the evaluation of the hand and wrist.

Introduction

The hand is one of the anatomical regions most frequently explored by ultrasound (US). This is for at least two main reasons. The first is related to the fact that this area is a common target in several rheumatic diseases. The second is linked to the relatively wide acoustic windows available for finger joints and tendons which permit careful depiction of critical details for rheumatological investigation. The hand is an anatomically complex region but in spite of this it should be regarded as a friendly area for the early training of rheumatologists in the difficult art of scanning since many pathognomonic changes of several important rheumatic diseases can be depicted at this level. The earliest investigations in hand US date back to the late 1980's with the availability of probes with frequencies > 10 MHz (1-3). For the first time soft tissue pathology of the hand and wrist could be approached employing high quality real time imaging and a new field of research started. Since then, several studies have demonstrated the great value of US imaging of the hand and wrist in rheumatology (4-16).

This paper provides the basic knowledge, reviews the available evidence and discusses the potential of US in the evaluation of the hand and wrist.

Indications

There are several clinical settings in which US examination of the hand and wrist may be beneficial (Table I). In early arthritis hand US is a sensitive tool for detecting both synovitis and bone erosions in small joints (13-16). It can also carefully depict sub-clinical tendon involvement in patients with chronic arthritis (17). US of the hand and wrist is also of great use in the identification of underlying pathology responsible for clinical scenarios such as "sausage finger" and "carpal tunnel syndrome" (18). The modality can therefore add vital information to tricky clinical situations in rheumatological practice.

Equipment

The availability of a very high frequency probe is a 'sine qua non' for a comprehensive evaluation of the entire US landscape of the hand. The use of linear probes with frequencies > 10 MHz is recommended. Another important feature to consider is the size and the shape of the probe: small "hockey stick" transducers allow an easier multi-planar assessment of the small joints of the hand because they can be readily placed among the fingers. Wide footprint and extended view reconstructions allow panoramic views that are particularly useful while assessing the anatomical structures of the wrist: radio-carpal and

Table I. Main indications for performing an US examination of hand and/or wrist.

Rheumatological setting	Indications for performing US examination
Early arthritis	To reveal bone erosions, especially at II MCP joint level. To detect synovitis (especially sub-clinical joint inflammation).
Tendon involvement	To detect tendon inflammation (especially sub-clinical involvement). To reveal tendon ruptures.
Dactylitis	To characterize the underlying pathologic substrate (synovitis, tenosynovitis, both synovitis and tenosynovitis, enthesitis).
Carpal tunnel syndrome	To visualize pathological conditions responsible for carpal tunnel syndrome. To depict morphostructural changes of the median nerve.
Wrist pain	To detect calcification or ruptures of the triangular ligament.
US guidance for injection therapy	To reduce risk of damage due to needle contact or steroid injection. To visualize correct placement of drug during injection.
Therapy monitoring in patients with chronic arthritis	To assess changes in soft tissue anatomy induced by therapy.

inter-carpal joints, carpal tunnel and extensor tendon compartments.

Power Doppler sonography (PDS) and colour Doppler sonography are now essential for assessment which also includes the study of tissue perfusion.

Scanning technique

Each anatomical structure must be explored through all the available acoustic windows using a multi-planar scanning technique. In particular, the articular cartilage of the metacarpal head requires maximal flexion of the metacarpophalangeal (MCP) joint to expose the maximal extent of its surface to the US beam. US examination of the II MCP joint must include evaluation of the lateral aspect of the joint where bone erosions, undetectable by conventional antero-posterior hand radiography, are most frequently discovered.

The tendons must be assessed from their musculo-tendinous origin to their distal insertion into bone. Dynamic real time examination is recommended for assessing the hand and wrist and is particularly true for the tendons and the median nerve. Active and passive tendon movement during US examination can confirm the presence of a tendon tear in cases where an intra-tendineous anechoic or hypoechoic area are found.

Both greyscale US and PDS mode require very low compression of the probe on the tissues under examination. Fluid collection in small joints can be readily displaced even by minimal external pressure and result in underestimation of joint effusion. Moreover, for proper PD examination of a joint, the patient must be asked to take a position generating the lowest intra-articular pressure. For the small joints of the hand, this position corresponds to the hand resting on the bed with a mild degree of flexion of the joints.

US anatomy

Joints

The articular surfaces of the small joints of the hand represent the landmarks to be visualised during US examination. In all cases the bone profile appears as a sharp, continuous and hyperechoic line generating an acoustic shadow. Particular attention should be paid during the evaluation of the anatomical neck of the metacarpal bone as it may be misinterpreted as bone erosion.

In healthy subjects the joint space is filled by the intra-articular fat pad which appears as an inverted triangular area with homogeneous echogenicity (19).

Normal articular cartilage appears as a homogeneous anechoic band delimited by sharply defined hyperechoic margins. The superficial chondro-synovial margin corresponds to the interface between the synovial fluid and the cartilage surface. This margin is thinner than the deeper one and its visualisation is optimised by perpendicular insonation of the US beam. (5). In healthy subjects, the thickness of the articular cartilage of the metacarpal head ranges from 0.2 to 0.5 mm (5).

In longitudinal scan, the triangular ligament of the carpus appears as a homogeneous echoic or hyper-echoic structure between the head of the ulna and the triquetrum bone and is best seen during abduction and adduction of the hand (20, 21).

Tendons

Morphostructurally, the finger flexor and extensor tendons appear on longitudinal scans, as tightly packed echoic bands with thin parallel linear echoes (fibrillar pattern) separated by fine anechoic lines. On transverse view, they have an oval-to-round shape and their echo-texture is characterised by tightly packed echoic dots with a homogeneous distribution (17, 22).

US examination of the tendons of the hand and wrist is relatively easy due to the absence of acoustic barriers and their relatively straight course. Active and passive movements of the fingers are very helpful when examining the carpal tunnel or the IV compartment of the wrist where more than four tendons lie next to one another.

The flexor and extensor tendons of the fingers are enveloped by a synovial sheath for the majority of their course. A subtle anechoic layer, indicating synovial fluid surrounding tendons with synovial sheath, can be visualized with very-high frequency transducers (>13 MHz). The size of this virtual space for the finger flexor tendons is 0.3 mm at the level of the MCP joints. The tendons and their tracts with synovial sheaths are listed in Table II (17). Mild tendon sheath widening on the dorsal aspect of the IV compartment of the wrist, proximal to the extensor retinaculum ligament is detectable in healthy subjects.

Median nerve

At the entrance to the carpal tunnel the median nerve is located between the tendon of flexor carpi radialis and the tendons of the flexor digitorum superficialis, deep to the tendon of palmaris longus, when present, and superficial to the flexor pollicis longus tendon.

The median nerve is similar in shape to a tendon on both longitudinal and transverse views. It can however, be recognised by its typical echo-texture with discrete hyper-echoic bundles on a hypo-echoic background delimited by a hyper-echoic margin (23). It is distinguished from tendons on real-time US examination where they run during finger flexion-extension movements in longitudinal views and change their echogenicity according to the angle of insonnation because of anisotropy on transverse scans.
In healthy subjects, the cross-sectional area of the median nerve can extend up to 10 mm^2 when measured at the level of the pisiform bone (24, 25).

Table II. Tendons of the hand and wrist with synovial sheath.

Tendons	Site where tendons are surrounded by synovial sheath
Abductor pollicis longus and extensor pollicis brevis	I compartment of the wrist
Extensor carpi radialis longus and brevis	II compartment of the wrist
Extensor pollicis longus	III compartment of the wrist
Extensor digitorum	IV compartment of the wrist
Extensor minimi	V compartment of the wrist
Extensor carpi ulnaris	VI compartment of the wrist
Flexor carpi radialis	At the level of the distal epiphysis of the radius and scaphoid bone
Flexor pollicis longus	Carpal tunnel, thenar eminence, thumb
Finger flexor tendons superficialis and profundus	There are two synovial sheaths: a common synovial sheath within the carpal tunnel and a single digitalis synovial sheath for each finger from the II to the V.
Flexor carpi ulnaris	Guyon canal

US pathology

Joints

Joint cavity widening is the US hallmark of synovitis. Enlargement of the joint space can be related to joint effusion and/or synovial proliferation. PDS is of value in the evaluation of synovial perfusion which may be patchy in its distribution, requiring an accurate multi-planar examination to assess its full extent. With the advent of the three-dimensional US, PDS interpretation will become simpler since a single three-dimensional image is able to con-

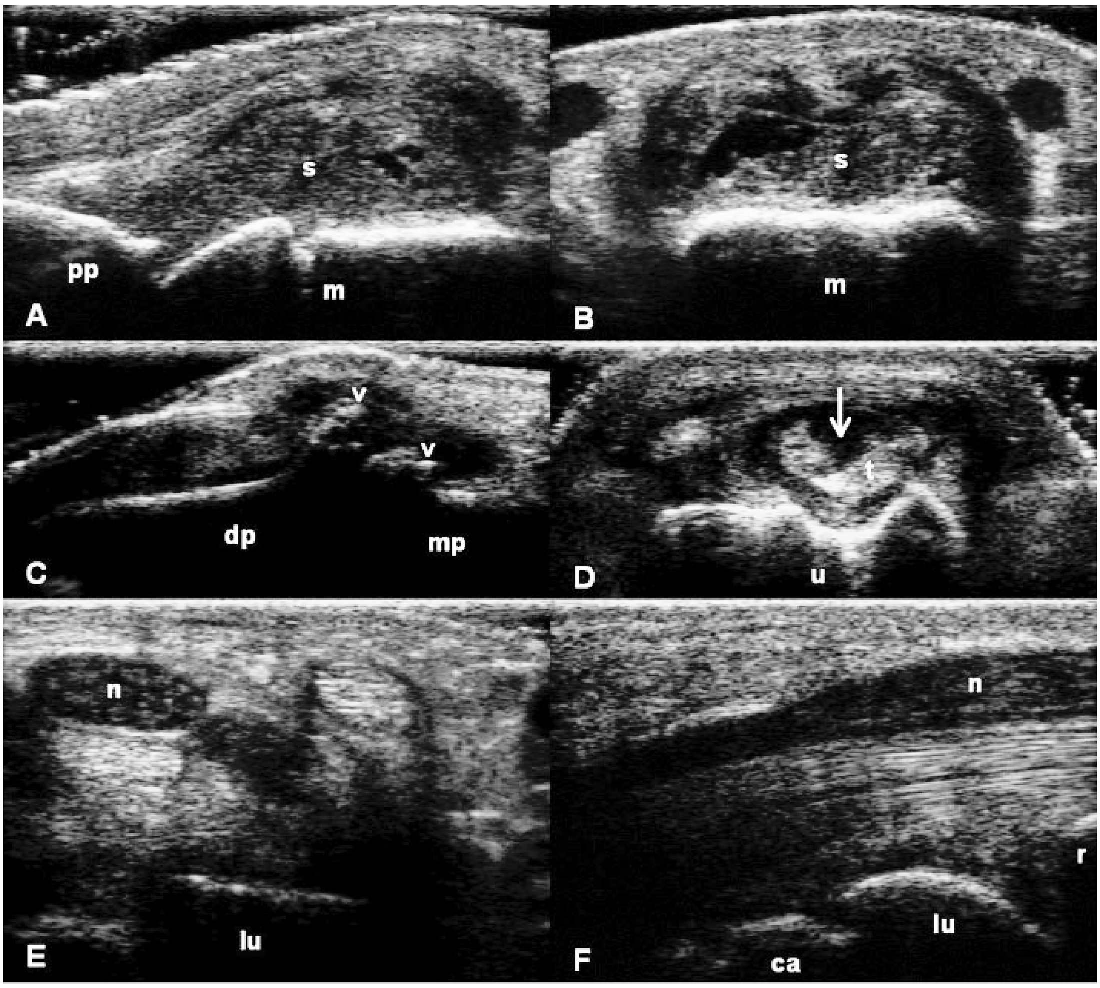

Fig. 1. Representative examples of hand and wrist US pathological findings. **A**-**B**. Rheumatoid arthritis. Proliferative synovitis (**s**) of a MCP joint on dorsal longitudinal (**A**) and transverse (**B**) views. **C**. Hederden node. Dorsal longitudinal scan showing osteophytes (**arrowheads**). **D**. Rheumtoid arthritis. Partial rupture (**arrow**) of the extensor carpi ulnaris tendon (**t**). **E**-**F**. Carpal tunnel syndrome. Marked thickening of the median nerve (**n**) at the proximal entrance of the carpal tunnel both on tranverse (**E**) and longitudinal (**F**) views. **m** = metacarpus; **pp** = proximal phalanx; **mp** = middle phalanx; **dp** = distal phalanx; **u** = ulna; **lu** = lunate bone; **ca** = capitate bone; **r** = radius.

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vey the full extent of PDS assessed by the US beam (26). Both greyscale and PDS findings of synovitis can be semi-quantitatively assessed using a scale of 0-3 (8, 11, 27). Bone erosion appears as an intra-articular discontinuity of the bone surface which is visible on at least two perpendicular scanning planes (19). In early rheumatoid arthritis (RA), US is more sensitive than X-ray in the detection of bone erosions especially on the lateral aspect of the second MCP joint (13, 14). Scoring of bone erosion has not been formally standardised to date but currently the most commonly used approach is to measure the maximal distance between the free edges of the erosion (13, 14).

In hand osteoarthritis, US demonstrates both inflammatory and degenerative changes. Osteophytes appear as single or multiple characteristic irregularities of the bone profile, located at the edges of the joint surfaces (28-30).

In chronic gout, US can detect deposition of urate crystals on the cartilage surface which appears as hyper-echoic enhancement of the superficial margin. Calcification of the triangular ligament of the wrist can be depicted as focal hyper-echoic areas, without acoustic shadow, which can be best visualised with dynamic evaluation.

Tendons

Tenosynovitis is the most frequent pathological condition involving the tendons of the hand and wrist in patients with chronic arthritis. The typical US finding in this setting is tendon sheath widening (17). This widening can be due to several factors including: increased amount of synovial fluid, increased volume of synovial tissue or a combination of synovial effusion and proliferation. On greyscale scanning the severity of tenosynovitis can be estimated by the extent of both sheath widening and synovial hypertrophy.

The distribution of PDS signal further characterises the severity of the tenosynovitis by providing information relating to the perfusion status of both the peri-tendineous synovial tissue and the tendon itself (31).

A broad spectrum of changes in tendon echotexture can be depicted in patients with hand arthritis including: diffuse tendon swelling with multiple small anechoic areas, focal anechoic and/or hypo-echoic loss of substance surrounded by an area of fibrillar derangement and subtotal tendon rupture (17). In patients with RA, US can show pannus within the synovial sheath breaching and invading the integrity of the tendon.

In chronic gout, tophaceous deposits can be depicted in the peri-articular soft tissues both surrounding or within the tendons. Intra-tendineous monosodium urate crystalline deposits appear as circumscribed areas of loss of normal fibrillar echotexture replaced by inhomogeneous echoic material covered with bright hyper-echoic spots. Depending on their size and/or density, tophaceous deposits may or may not generate an acoustic shadow (29).

Median nerve

The most relevant pathological finding relating to the median nerve is the change of its cross-sectional area. An increment of the transverse area of the nerve at the proximal entrance to the carpal tunnel is the most frequent and non-specific sign of high pressure within the tunnel.

US can also identify secondary causes of carpal tunnel syndrome (18). These include tenosynovitis of the finger flexor tendons, synovitis of the radio-carpal and/or inter-carpal joints, aberrant muscle and tophaceous deposits. A circumscribed reduction of the thickness of the median nerve is also a morphological change indicative of a secondary cause of carpal tunnel syndrome. This condition is almost invariably related to the presence of a post-surgical connective adhesion band.

Sonographic guided procedures

The value of US as a tool for the accurate positioning of a needle into the small joints of hand and wrist for injection of therapeutic substances, joint fluid aspiration and for synovial biopsy has been documented in several studies (32-34). It may also be used for diagnostic aspiration of distended tendon sheaths in cases where sepsis must be excluded in the differential diagnosis.

Controversial issues

In spite of the wealth of available evidence supporting the value of US in the detection of synovitis and bone erosion in patients with RA, quantitative assessment of these specific entities remains a matter of debate. Agreement on these US parameters of inflammation will be the topic of future research particularly in terms of therapeutic monitoring. Currently, a four point scoring system appears to be the most widely used and appropriate method for semi-quantitative evaluation of both greyscale and PDS findings in synovitis. Consensus upon the quantitative assessment of bone erosion still has to be reached.

It seems likely that the hand and wrist will continue to be one of the main anatomical targets for research and development in the field of US worldwide.

Link

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References

1. FORNAGE BD: Soft-tissue changes in the hand in rheumatoid arthritis: evaluation with US. *Radiology* 1989; 173: 735-7.
2. VINCENT LM: Ultrasound of soft tissue abnormalities of the extremities. *Radiol Clin North Am* 1988; 26: 131-44.
3. DE FLAVIIS L, SCAGLIONE P, NESSI R, VENTURA R, CALORI G: Ultrasonography of the hand in rheumatoid arthritis. *Acta Radiol* 1988; 29: 457-60.
4. GRASSI W, TITTARELLI E, BLASETTI P, PIRANI O, CERVINI C: Finger tendon involvement in rheumatoid arthritis: evaluation with highfrequency sonography. *Arthritis Rheum* 1995; 38: 786-94.
5. GRASSI W, TITTARELLI E, PIRANI O, AVALTRONI D, CERVINI C: Ultrasound examination of metacarpophalangeal joints in rheumatoid arthritis. *Scand J Rheumatol* 1993; 22: 243-7.
6. MAGNANI M, SALIZZONI E, MULE R, FUSCONI M, MELICONI R, GALLETTI S: Ultrasonography detection of early bone erosions in the metacarpophalangeal joints of patients with rheumatoid arthritis. *Clin Exp Rheumatol* 2004; 22: 743-8.
7. TAYLOR PC, STEUER A, GRUBER J *et al.*: Ultrasonographic and radiographic results from a two-year controlled trial of immediate or one-year-delayed addition of infliximab to ongoing methotrexate therapy in patients with erosive early rheumatoid arthritis. *Arthritis Rheum* 2006; 54: 47-53.
8. SZKUDLAREK M, COURT-PAYEN M, JACOBSEN S, KLARLUND M, THOMSEN HS, OSTERGAARD M: Interobserver agreement in ultrasonography of the finger and toe joints in

rheumatoid arthritis. *Arthritis Rheum* 2003; 48: 955-62.
9. SZKUDLAREK M, COURT-PAYEN M, STRANDBERG C, KLARLUND M, KLAUSEN T, OSTERGAARD M: Power Doppler ultrasonography for assessment of synovitis in the metacarpophalangeal joints of patients with rheumatoid arthritis: a comparison with dynamic magnetic resonance imaging. *Arthritis Rheum* 2001; 44: 2018-23.
10. NAREDO E, GAMERO F, BONILLA G, USON J, CARMONA L, LAFFON A: Ultrasonographic assessment of inflammatory activity in rheumatoid arthritis: comparison of extended versus reduced joint evaluation. *Clin Exp Rheumatol* 2005; 23: 881-4.
11. WEIDEKAMM C, KOLLER M, WEBER M, KAINBERGER F: Diagnostic value of high-resolution B-mode and doppler sonography for imaging of hand and finger joints in rheumatoid arthritis. *Arthritis Rheum* 2003; 48: 325-33.
12. BIANCHI S, MARTINOLI C, SUREDA D, RIZZATTO G: Ultrasound of the hand. *Eur J Ultrasound* 2001; 14: 29-34.
13. GRASSI W, FILIPPUCCI E, FARINA A, SALAFFI F, CERVINI C: Ultrasonography for the evaluation of bone erosions. *Ann Rheum Dis* 2001; 60: 98-103.
14. WAKEFIELD RJ, GIBBON WW, CONAGHAN PG *et al.*: The value of sonography in the detection of bone erosions in patients with rheumatoid arthritis: a comparison with conventional radiography. *Arthritis Rheum* 2000; 43: 2762-70.
15. BROWN AK, WAKEFIELD RJ, CONAGHAN PG, KARIM Z, O'CONNOR PJ, EMERY P: New approaches to imaging early inflammatory arthritis. *Clin Exp Rheumatol* 2004; 22: S18-25.
16. SCHEEL AK, HERMANN KG, KAHLER E *et al.*: A novel ultrasonographic synovitis scoring system suitable for analyzing finger joint inflammation in rheumatoid arthritis. *Arthritis Rheum* 2005; 52: 733-43.
17. GRASSI W, FILIPPUCCI E, FARINA A, CERVINI C: Sonographic imaging of tendons. *Arthritis Rheum* 2000; 43: 969-76.
18. GRASSI W, FILIPPUCCI E, CAROTTI M, SALAFFI F: Imaging modalities for identifying the origin of regional musculoskeletal pain. *Best Pract Res Clin Rheumatol* 2003; 17: 17-32.
19. WAKEFIELD RJ, BALINT PV, SZKUDLAREK M *et al.*: Musculoskeletal ultrasound including definitions for ultrasonographic pathology. *J Rheumatol* 2005; 32: 2485-7.
20. KEOGH CF, WONG AD, WELLS NJ, BARBARIE JE, COOPERBERG PL: High-resolution sonography of the triangular fibrocartilage: initial experience and correlation with MRI and arthroscopic findings. *AJR* 2004; 182: 333-6.
21. CHIOU HJ, CHANG CY, CHOU YH *et al*. Triangular fibrocartilage of wrist: presentation on high resolution ultrasonography. *J Ultrasound Med* 1998; 17:41-8.
22. MARTINOLI C, BIANCHI S, DERCHI LE: Tendon and nerve sonography. *Radiol Clin North Am* 1999; 37: 691-711.
23. SILVESTRI E, MARTINOLI C, DERCHI LE, BERTOLOTTO M, CHIARAMONDIA M, ROSENBERG I: Echotexture of peripheral nerves: correlation between US and histologic findings and criteria to differentiate tendons. *Radiology* 1995; 197: 291-6.
24. EL MIEDANY YM, ATY SA, ASHOUR S: Ultrasonography versus nerve conduction study in patients with carpal tunnel syndrome: substantive or complementary tests? *Rheumatology* 2004; 43: 887-95.
25. WONG SM, GRIFFITH JF, HUI AC, TANG A, WONG KS: Discriminatory sonographic criteria for the diagnosis of carpal tunnel syndrome. *Arthritis Rheum* 2002; 46: 1914-21.
26. STRUNK J, LANGE U: Three-dimensional power Doppler sonographic visualization of synovial angiogenesis in rheumatoid arthritis. *J Rheumatol* 2004; 31: 1004-6.
27. FILIPPUCCI E, FARINA A, CAROTTI M, SALAFFI F, GRASSI W: Grey scale and power Doppler sonographic changes induced by intra-articular steroid injection treatment. *Ann Rheum Dis* 2004; 63: 740-3.
28. IAGNOCCO A, COARI G: Usefulness of high resolution US in the evaluation of effusion in osteoarthritic first carpometacarpal joint. *Scand J Rheumatol* 2000; 29: 170-3.
29. GRASSI W, FILIPPUCCI E, FARINA A, CERVINI C: Sonographic imaging of the distal phalanx. *Semin Arthritis Rheum* 2000; 29: 379-84.
30. IAGNOCCO A, CERIONI A, COARI G, OSSANDON A, MASCIANGELO R, VALESINI G: High resolution ultrasonography in detection of bone erosions in patients with hand osteoarthritis. *J Rheumatol* 2005; 32: 2381-3.
31. BREIDAHL WH, STAFFORD JOHNSON DB, NEWMAN JS, ADLER RS: Power Doppler sonography in tenosynovitis: significance of the peritendinous hypoechoic rim. *J Ultrasound Med* 1998; 17: 103-7.
32. GRASSI W, LAMANNA G, FARINA A, CERVINI C: Synovitis of small joints: sonographic guided diagnostic and therapeutic approach. *Ann Rheum Dis* 1999; 58: 595-7.
33. RAZA K, LEE CY, PILLING D *et al.*: Ultrasound guidance allows accurate needle placement and aspiration from small joints in patients with early inflammatory arthritis. *Rheumatology* 2003; 42: 976-9.
34. VAN VUGT RM, VAN DALEN A, BIJLSMA JW: Ultrasound guided synovial biopsy of the wrist. *Scand J Rheumatol* 1997; 26: 212-4.