*Review*

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# Ultrasound of the knee in rheumatology

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**Abstract**

Knee ultrasound is a very useful tool for the clinical examination of rheumatic patients. In the last years many papers have been focused on this subject, exhibiting a high degree of improvement since the first musculoskeletal ultrasound paper concerning the knee was published 30 years ago. Apart from the accurate description of anatomic landmarks and structures and also of the basic pathological findings (fluid, synovitis, enthesitis, osteophytes), rheumatologic research has focused on inflammatory findings quantification and their reaction to remissive treatments. The aim of this review is to describe the normal ultrasonographic appearance of knee structures concisely and mainly to analyse the literature about pathological findings in the knee joint.

**Keywords:** ultrasound, knee, anatomy, pathology

## Introduction

Although the knee is widely considered to be the most accessible joint for clinical examination, knee ultrasound (US) was proven to be superior in both accuracy and reproducibility when compared to the clinical exam [1].

Being a relatively deep joint, the use of low freqwency probes is recommended for knee US. The first published US image of a human joint referred to the knee, specifically to differentiate Baker's cyst from thrombophlebitis, and was performed in 1972 [2]. Since then, many papers have focused on this subject and discovered elements of anatomy and main pathology of the knee.

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The aim of this review is to analyse the recent literature on this subject, focusing first on a brief description of the knee anatomy, and then on the most relevant pathologic aspects of rheumatic disease.

## US scanning technique

Standardized scanning of the knee is performed with a linear 5-13 MHz transducer, except for the most superficial structures that might need a 15 MHz probe [3]. The patient's position depends on the area depicted: dorsal decubitus with a slight knee flexion for the anterior side and ventral decubitus with extended knee for posterior side.

## US anatomy

For didactic reasons, the knee will be divided in four compartments: anterior, medial, lateral, and posterior. The main anatomic structures from these compartments are summarized in tables I and II together with the transducer position in order to maximize their visualization (table I) and the ultrasonographic correspondent image (table II). US assessments are more helpful if the ex-

Table I. Main anatomic structures and related ultrasonographic scans

| Compartment | Structure | Transducer position |
|---|---|---|
| Anterior | Quadriceps tendon (Qt) | Longitudinal scan |
| | Patellar tendon (Pt) | Longitudinal scan |
| | Suprapatellar recess (S) | Longitudinal scan |
| | Prefemoral fatpad (Pf) | Longitudinal scan |
| | Suprapatellar fatpad ( Sf) | Longitudinal scan |
| | Patella (P) | Longitudinal scan |
| | Tibial tuberosity (Tt) | Longitudinal scan |
| | Cartilage ( C) | Transverse scan |
| Medial | Tibiofemoral medial joint | Longitudinal scan |
| | Medial meniscus (Mm) | Longitudinal scan |
| | Medial collateral ligament (MCL) | Longitudinal scan |
| | Semimembranosus insertion(Sm) | Transverse scan |
| | Pes anserine insertion(Pa) | Longitudinal scan |
| Lateral | Lateral tibiofemoral joint space | Longitudinal scan |
| | Lateral meniscus (Lm) | Longitudinal scan |
| | Lateral collateral ligament(LCL) | Longitudinal scan |
| | Iliotibial band(Itb) | Longitudinal scan |
| | Popliteus tendon(PoT) | Transverse scan |
| | Biceps femoris insertion | Longitudinal scan |
| | Peroneal nerve | Transverse scan |
| Posterior | Posterior horns of menisci | Longitudinal scan |
| | Femoral condyles cartilage | Longitudinal scan |
| | Gastrocnemius muscle(GM) | Transverse scan |
| | Gastrocnemius tendon(Gt) | Transverse scan |
| | Semimembranosus tendon(Sm) | Transverse scan |
| | Popliteal artery and veins(PV) | Transverse scan |

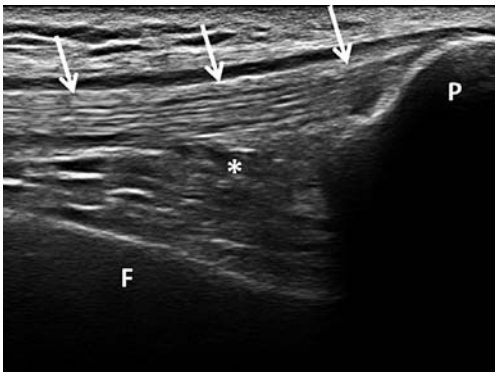


**Fig 1.** Ultrasound of the knee in a healthy individual. Longitudinal anterior scan at the suprapatellar recess level. Normal quadriceps tendon (↑) and normal amount of synovial fluid (*) are visualized. F: femur; P: patella

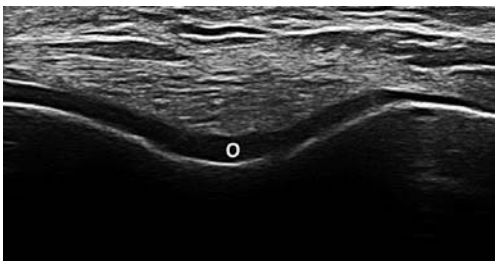


**Fig 2.** Ultrasound of the knee in a healthy individual. Transverse suprapatellar scan. Normal hyaline cartilage of the femoral condyles (o) is visualized.

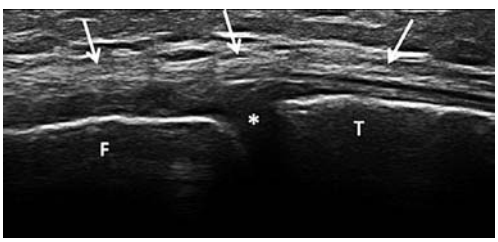


**Fig 3.** Ultrasound of the knee in a healthy individual. Longitudinal scan of the medial aspect of the joint. Normal medial collateral ligament (↑) and normal internal meniscus (*) are visualized. F: femur; T: tibia

aminations are dynamic, covering most of the region of interest, and if depicted structures (muscles, tendons, ligaments, nerves, cartilage, menisci, and cortical bone) are visualized in their entire length. Moreover, since panoramic views are available on most of the recently used US machines, it is now possible to depict in one image the whole length of a structure, regardless of its dimensions. US representative images of anterior and medial compartments are visualised in figures 1-3.

**US pathology**

**1. Joint effusion and synovial hypertrophy**

An amount of fluid of more than 3 ml can be depicted in the knee joint with US [3] (fig 4). Three recesses of knee synovia are visualized by US on the anterior part of the knee: suprapatellar, parapatellar lateral, and parapatellar medial. As fluid is displaceable, care should be taken to avoid pressure with the probe. The

Table II. Main anatomic structures depicted by ultrasound and related sonographic pattern

| Compartment | Structure | Ultrasonographic aspect |
|---|---|---|
| Anterior | Quadriceps tendon (Qt) | Fibrillar hypoechoic structure inserting on superior pole of the patella |
| | Patellar tendon (Pt) | Fibrillar hypoechoic structure inserting on inferior pole of the patella and on tibial tuberosity |
| | Suprapatellar recess (S) | Hypo/anechoic line between prefemoral and suprapatellar fatpad |
| | Prefemoral fatpad (Pf) | Hyperechoic structure on top of femoral cortex |
| | Suprapatellar fatpad ( Sf) | Hyperechoic structure under quadriceps tendon insertion |
| | Patella (P) | Hyperechoic line |
| | Tibial tuberosity (Tt) | Hyperechoic line |
| | Cartilage ( C) | Anechoic band parallel to trochlea, knee in hyperextension |
| Medial | Tibiofemoral medial joint | Two bony heads ( hyperechoic) coming together |
| | Medial meniscus (Mm) | Hyperechoic triangle inside the joint |
| | Medial collateral ligament (MCL) | Fibrillar hyperechoic structure from medial epycondyle to anteromedial tibia |
| | Semimembranosus insertion(Sm) | Hyperechoic ovoid in a sulcus near medial meniscus |
| | Pes anserine insertion(Pa) | Hyperechoic structure inserting together with MCL, on top of it |
| Lateral | Lateral tibiofemoral joint space | Two bony heads coming together |
| | Lateral meniscus (Lm) | Hyperechoic triangle inside the joint |
| | Lateral collateral ligament(LCL) | Hypoechoic structure over the joint space with sinuous traject |
| | Iliotibial band(Itb) | Hyperechoic structure inserting on Gerdy's tubercle on tibia |
| | Popliteus tendon(PoT) | Hyperechoic ovoid in a sulcus next to lateral meniscus |
| | Biceps femoris insertion | Hyperechoic structure inserting on fibular head, on top of LCL |
| | Peroneal nerve | Hyperechoic ovoid with dots inside near fibular head |
| Posterior | Posterior horns of menisci | Hyperechoic triangles on lateral and medial joint spaces |
| | Femoral condyles cartilage | Anechoic band parallel to bony cortex |
| | Gastrocnemius muscle(GM) | Hypoechoic pennate structure |
| | Gastrocnemius tendon(Gt) | Hyperechoic triangle on top of gastrocnemius muscle |
| | Semimembranosus tendon(Sm) | Hyperechoic ovoid next to gastrocnemius |
| | Popliteal artery and veins(PV) | Anechoic ovoids with Doppler signal inside, veins compressible |

usual knee fluid assessment starts with the suprapatellar recess, and continues with the lateral and medial recesses, as they are the most dependent when the patient is in dorsal decubitus. After effusion detecting, compression with the transducer is recommended, in order to differentiate between fluid and synovial hypertrophy (fig 5), which is not displaceable. The development of Power Doppler US (PDUS) technique has lead to improving information regarding the local activity, knowing that PDUS detects inflamed tissues hyperemia. The knee is a relatively deep joint, so PDUS signal isl not always present in case of synovitis. However, its presence is indicative of active inflammation.

The superiority of US examination over clinical exam in the swollen knee was proven first by Hauzeur et al [1], and a few years later by Kane et al regarding Rheumatoid Arthritis (RA) fluid in the knee [4]. This applies for suprapatellar recess, parapatellar lateral and medial,

and Baker cysts. On the other hand, clinical exam proved itself to underestimate knee inflammation.

Effusion is defined by OMERACT as an abnormal hypoechoic or anechoic intraarticular material that is compressible and displaceable and does not exhibit Doppler signal. Synovial hyperthropy is defined as an abnormal hypoechoic intra-articular tissue that is nondisplaceable and poorly compressible and may exhibit the Doppler signal [5]. The dimensions can be evaluated by the direct measurement of knee effusion at its greatest point of thickness inside the suprapatellar recess [6], and in that case a >3mm diameter of suprapatellar recess is considered pathologic [7].

The presence of the PDUS signal inside the knee joint can be used to differentiate between hypervascular and fibrous pannus, but it might not always be accurately visualized, mainly because of the deep location of the joint. Fiocco et al proved that by using contrast enhanced Doppler (CED), the method has enhanced reliability, consistently reducing artefacts, when comparing to arthroscopy as the gold standard [8]. However, the use of contrast agents can be considered time consuming and therefore cannot be used in daily practice.

Knee synovitis in RA is sometimes refractory (persistent for more than 6 months of aggressive local and systemic treatment) or relapsing during the treatment, and that may cause great damage to the joint, leading frequently to arthroplasty. This is another important reason for the indication of repeated examinations of the knee joint by US especially in RA. As quantification of disease activity in RA is an important issue nowadays for starting or monitoring biologic treatment, US became very important together with clinical scores for global evaluation. More than 10 different US scores were defined in the last years, including different joints, mostly hand joints. The knee was also included in some of these scores [9-11]. The possibility of developing US scores emerged from the description of the semiquantitative scale as a quantifying method with high reproducibility [12]. US scores are based on adding the values of semiquantitative grades in specific joints (from a scale 0-3). This modality of quantification being relatively easy, can be applied to large joints as knee as well.

US is frequently used to evaluate the therapeutic intervention in the RA knee. Fiocco et al tested the specific action of Etanercept on RA and Psoriatic arthritis patient's knees, in patients with persistent knee synovitis after methotrexate and other DMARDs. The conclusion was that Etanercept can suppress persistent knee synovitis in most patients [13]. Regarding PDUS, the study reported the decrease in vascularization first in the superficial layer of knee pannus, and later in the deeper one. The

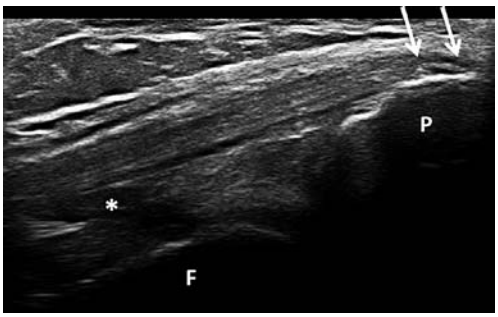


**Fig 4.** Ultrasound of the knee. Longitudinal anterior scan of the suprapatellar recess showing the presence of enthesophytes at the quadriceps tendon's enthesis (↑) and mild effusion (*). F: femur; P: patella

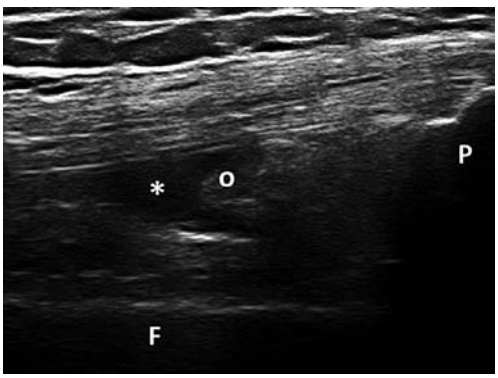


**Fig 5.** Ultrasound of the knee. Longitudinal anterior scan of the suprapatellar recess showing the presence of mild effusion (*) and mild synovial hypertrophy (o). F: femur; P: patella

separation between the two layers of inflammation inside knee synovitis was reanalysed by Kasukawa et al [14]. Superficial flow signals were defined as located in the superficial half of the pannus and fluid space whereas deep flow signals were located in the deep half of the pannus. Joints with superficial pattern had a higher flow signal and a higher synovial effusion grade, whereas joints with deep pattern had a higher grade of synovial proliferation.

In a systematic review focusing on the responsiveness of knee arthritis to therapy, Keen et al [15] reviewed the studies in which US synovitis of the knee was assessed (Gray Scale and PD) before and after a therapeutic intervention. The authors defined internal responsiveness as the ability of an outcome tool to demonstrate temporal changes in response to therapy and external responsiveness as the extent to which changes in an outcome tool correlate with other referenced measures [15]. US of the knee demonstrated internal responsiveness with regard to synovial thickness, effusion size and popliteal cyst size

in 3 studies, while other 4 studies found correlations between US and subjective measurements of health status [15]. Unfortunately, the authors found a great heterogeneity of working methods in knee US examintaion, leading to the conclusion that US still needs a great work for standardization.

In a pilot study on 104 knees, Vlad et al revealed that effusion dimensions measured in RA knees are strongly correlated to the pain expressed by the patient quantified using the VAS score in the same day as the US examination in a blind manner [16].

Trying to study the prevalence of US pathologic abnormalities encountered in RA knees, Riente et al discovered effusion in 70% of the 200 knees; 82% of these had synovial hypertrophy accompanying the effusion, with only 19% a PD positive signal [17]. In a psoriatic arthritis group comprising 186 knees, Delle Sedie et al discovered in 84.3% of joints at least one sign of inflammation (effusion and/or synovial hypertrophy) [18].

Regarding knee osteoarthritis, a report of the EULAR on US use in this pathology discovered in 600 patients examined, 53.7% with no signs of inflammation (effusion or synovitis), 29.5% with joint effusion alone, 14.2% with both synovitis and effusion, and 2.7% with synovitis alone [19,20]. Inflammation found by US correlated well to advanced radiographic disease on the Kellgren-Lawrence scale, but not to pain intensity during recent physical activity. The explanation could be linked to the pain source in osteoarthritis, which may be especially linked to bone oedema, seen only on MRI. However, the presence of inflammatory signs on US suggests an inflammatory pathway for osteoarthritis, too.

Proofs regarding inflammation in osteoarthritis are increasing; in a recent study, Clockaerts et al showed cytokine production by infrapatellar fatpad [21]. It is still unclear how inflammation can affect the natural evolution of osteoarthritis. Chao et al [22] examined clinically and by US 79 patients with symptomatic knee osteoarthritis, and then infiltrated their knees with corticosteroids/placebo after randomization. The conclusion was that corticosteroids have a short time effect on knee pain compared to placebo. They also defined the concept of US inflammatory signs in osteoarthritis by the presence of intraarticular synovial hypertrophy with or without effusion. „Inflammatory patients" were called patients with knee effusion and they were proven to experience a shorter benefit from steroids injection than the patients with a dry knee joint. In conclusion, lack of synovitis on US may be a good prognostic sign, showing that symptoms might be easily controlled by intraarticular steroids. This was the first study to prove the ability of US exam to predict response to a treatment.

**2. Baker's cyst and other knee bursitis**

Popliteal cysts were first described by Adams in 1840, but Baker in 1877 established the causality relation with joint effusions and offered the definition [23]. Gastrocnemius and semimebranosus bursitis is called Baker cyst. It communicates with the joint through the bursal's neck – the joint fluid accumulates in the bursa in knee flexion and cannot go back due to the one-way valve mechanism [3]. Sometimes, Baker cysts may be giant and ruptured into the calf, causing inflammation resembling thrombophlebitis. The differential diagnosis between these two entities can be easily done by US examination. Any disease causing fluid accumulation inside the knee can lead to a Baker cyst formation.

The general prevalence of Baker cysts in population is evaluated with many variations. In a study comparing MRI with US in the detection of Baker's cysts, US detected 100% of the MR detected cysts [24]. The incidence of Baker's cysts in a group of 99 consecutive patients with RA was 33.8% [ 25]. In a group of 100 patients programmed to knee arthroscopy for various reasons the incidence of Baker's cyst was 20% [26]; in a study by Ward et al, out of 36 evaluated pathological knees, 58% had Baker's cysts [24]. Although the incidence is not clearly established yet, the popliteal fossa must be examined every time when knee US is performed, especially when fluid is found in the anterior recesses.

The content of a cyst may be variable depending on the base pathology- cysts may contain fluid (anechoic image), synovial hypertrophy (hypoechoic images inside, sometimes with cauliflower aspect resembling knee synovitis), calcifications, osteochondral fragments. If Baker cysts develop slowly, the patient may be asymptomatic.

Baker cysts were proven to regress following remissive treatment in RA together with knee synovitis [24-26].

Other knee bursitis are prepatellar and infrapatellar bursitis. Prepatellar bursitis is superficially located, and it is mainly posttraumatic. Infrapatellar bursitis is superficial (in continuation with prepatellar bursitis, over the last third of the patellar tendon), or deep (between the patellar tendon and Hoffa's fatpad). Deep infrapatellar bursitis can accompany tendon and entheseal pathology of that area. An important aspect to mention is that while no fluid is normally found in prepatellar bursitis, a small amount in deep infrapatellar bursa is common in healthy subjects [3].

**3. Tendon and entheseal pathology**

The most encountered knee tendon pathology in rheumatology is the inflammation of their bony insertion known as enthesitis, widely considered as the hallmark

for spondylarthropathies (SpA). It is also known that enthesitis may affect primarily lower limbs, knee together with the heel being the most frequently affected joints.

US definition of enthesopathy includes an abnormally hypoechoic and/or thickened tendon at its bony attachment, occasionally with calcifications, seen in two perpendicular planes that may exhibit a Doppler signal, and also bony changes – entesophytes, erosions or irregularities [5] (fig 4). The inflammatory enthesopathy is known as enthesitis and it has been widely studied with US, mostly since biologic treatment emerged in SpA and had to be objectively monitored.

The quadriceps tendon insertion and the patellar tendon/ligament both insertions, as well as suprapatellar and infrapatellar bursitis were included in the GUESS score, one of the first available US scores to quantify enthesitis [27]. The study found numerous subclinical enthesitis in SpA and proved US to be more sensitive and more specific than clinical examination. GUESS score, consisting only in Gray Scale examinations, was proven reproducible for treatment evaluation of SpA patients, but values obtained did not correlate to systemic parameters of disease activity, like in RA.

Adding PDUS to knee enthesitis evaluation, D'Agostino et al found abnormal vascularization in 81% out of 164 consecutive SpA patients; in the knee, quadriceps tendon was less affected than patellar tendon [29]. An important conclusion of the study was that US shows enthesitis signs ( PDUS) mostly in SpA patients with peripheral form of disease – psoriatic arthritis and reactive arthritis [28,29].

Regarding enthesitis response to treatment, Naredo et al investigated a group of 327 patients with SpA before and after anti-TNF alfa treatment. They concluded that enthesis morphologic abnormalities, PD signal and bursitis are active inflammatory lesions responsive to biologic therapy, and calcifications and bone lesions are not responsive, being them as structural damage lesions [30]. The same three enthesis points were included from the knee. Together with enthesitis, the presence of synovial effusion was also considered as inflammatory, being reversible to treatment.

Enthesitis of the quadriceps tendon was found also in RA patients [31], less common than in psoriatic patients, and always accompanied by effusion. Also, inflammatory signs previously described appear more often in RA whereas in psoriatic arthritis patients exhibit more structural damage.

**4. Bone and cartilage abnormalities**

Knee osteoarthritis is one of the most encountered diseases among general population, with a women predilection. The most specific US sign for osteoarthritis are the osteophytes, defined as step-up bony prominence at the end of the normal bony contour or at the margin of the joint seen in two perpendicular planes, with or without acoustic shadow [27] (fig 6). In the knee joint, the place to look for osteophytes is the tibiofemoral joint. In advanced disease, osteophytes can permanently compromise the joint structures (capsule, menisci or ligaments), leading to secondary pathology (ligament rupture, meniscal clefts or meniscal cysts). The indication for US is in the early stage of the disease, mainly for diagnosis.

Cartilage at the knee joint has a thickness of about 3mm [27] (fig 2). Signs of deterioration appear on US as blurring, loss of sharp contour, and margin irregularities. Usually in osteoarthritis the cartilage is asymmetrically thinned, being more symmetrically affected in RA. Knee cartilage is best visualized at the patellar level, with hyperflexed knee, and also from the posterior view, along femoral condyles.

US was recently proven to be very accurate in cartilage depiction of knee condylar cartilage in cadaver specimen [32].

**5. Knee joint injection**

Intraarticular joint injections of the knee are performed frequently in rheumatologic daily practice. The placement of the needle must be strictly inside the joint, no matter if the maneuver is for aspirating fluid or for therapeutic agents injection (corticosteroids or viscosupplementation substances). Only 56-85% of intraarticular (IA) injections are correctly placed [33,34], without using an imaging modality to guide the needle. Other studies demonstrate a higher rate for non guided IA knee injection – up to 93% [35-37]. Sonographic needle guidance has been proven to enhance clinical outcomes (pain control) and cost-effectiveness of the procedure [36]. Balint et al reported a 4/10 rate of success in a blinded aspiration of the knee, compared to 18/19 when using US [37].

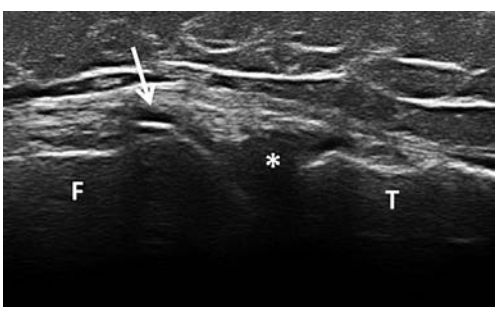


**Fig 6.** Ultrasound of the knee. Longitudinal scan of the medial aspect of the joint showing the presence of an osteophyte (↑). Normal internal meniscus (*) is also visualized. F: femur; T: tibia

In a systematic review, Hermans et al [38] included nine studies on the matter of needle placement inside knee joint. The most accurate (and the most used) approach of the knee is the superolateral one, with the knee in extension, resulting in a 91% pooled accuracy. Other approaches are lateral mid-patellar, anterolateral and anteromedial approach, which showed a lower accuracy. A medial patellar approach was used by Sang Hee et al to guide intraarticular hyaluronan in a dry knee- the guided injections had an accuracy of 95,6% compared to 77.3% in blinded injections [39].

The main agents used for knee IA injections are corticosteroids, both in refractory synovitis in inflammatory conditions (RA, SpA, PsA) and for symptomatic relief in OA. IA corticosteroids are recommended by ACR guidelines of knee RA/ OA treatment since 2002/2000 [40,41].

US guided knee injection is able to improve the accuracy from 82% in a blinded manner to 91%, even if the rheumatologist was a young doctor with basic US training in the Cunnington et al study [42]. The minimal difference between the two types of procedure was only obtained for the knee, suggesting that for the other joints the need for US guidance is higher.

The use of viscosupplementation for knee OA is also comprised in ACR guidelines for treatment [40]. Hyaluronan treatment is mostly indicated in painful knee OA with no or mild effusion [43]. US highly improves IA needle placement in such conditions, and its importance is augmented by the fact that the periarticular hyaluronic acid injection showed no improvement in knee pain.

## Conclusion

US of the knee is a very frequently encountered procedure, both for clinical practice and for research purposes. Knee US, should be performed in all patients with RA as well as in OA, US evaluation of the knee enhances the possibility of detecting and extracting fluid. Recognizing the presence of knee effusion is not always easy at clinical examination. With US, even a beginner can obtain very good results in detecting knee effusion. In a recent study, 21 medical students were able to detect knee injected fluid on cadavers, after a few hours of teaching [44]. This is a strong reason for introducing US in rheumatology teaching process at all levels.

**Conflict of interest**: none

## References

1. Hauzeur JP, Mathy L, De Maertelaer V. Comparison between clinical evaluation and ultrasonography in detecting hydrarthrosis of the knee. J Rheumatol 1999;26:268-2683.
2. McDonald DG, Leopold GR. Ultrasound B-scanning in the differentiation of Baker's cyst and thrombophlebitis. Br J Radiol 1972;45:729–732.
3. Bianchi S, Martinolli C. Ultrasound of the musculoskeletal system. Springer Berlin Heidelberg New York 2007:637-638.
4. Kane D, Balint PV, Sturrock RD. Ultrasonography is superior to clinical examination in the detection and localization of knee joint effusion in rhaumatoid arthritis. J Rheumatol 2003;30:966-971.
5. Wakefield RJ, Balint PV, Szkudlarek M, et al; OMERACT 7 Special Interest Group. Musculoskeletal ultrasound including definitions for ultrasonographic pathology. J Rheumatol 2005;32:2485-2487.
6. Court-Payen M. Sonography of the knee: intra-articular pathology. J Clin Ultrasound 2004;32:481-490.
7. Naredo E, Bonilla G, Gamero F, Uson J, Carmona L, Laffon A. Assessment of inflammatory activity in rheumatoid arthritis: a comparative study of clinical evaluation with grey scale and power Doppler ultrasonography. Ann Rheum Dis 2005;64:375-381.
8. Fiocco U, Ferro F, Cozzi L, et al. Contrast medium in power Doppler ultrasound for assessment of synovial vascularity: comparison with arthroscopy. J Rheumatol 2003;30:2170-2176.
9. Naredo E, Rodriguez M, Campos C, et al. Validity, reproducibility and responsiveness of a twelve-joint simplified power doppler ultrasonographic assessment of joint inflammation in rheumatoid arthritis. Arthritis Rheum 2008;59:515-522.
10. Iagnocco A, Fillippucci E, Perella C, et al. Clinical and ultrasonographic monitoring response to adalimumab tratment in rheumatoid arthritis. J Rheumatol 2008;35:35-40.
11. Hammer HB, Sveinsson M, Kongtorp AK, Kvien TK. A 78 joints ultrasonographic assessment is associated with clinical assessments and is highly responsive to improvement in a longitudinal study of patients with rheumatoid arthritis starting adalimumab treatment. Ann Rheum Dis 2010;69:1349-1351.
12. Szkudlarek M, Court-Payen M, Jacobsen S, Klarlund M, Thomsen HS, Østergaard M. Interobserver agreement in ultrasonography of the finger and toe joints in rheumatoid arthritis. Arthritis Rheum 2003;48:955-962.
13. Fiocco U, Ferro F, Vezzu M, et al. Rheumatoid and psoriatic knee synovitis: clinical, grey scale and power doppler ultrasound assessment of the response to etanercept. Ann Rheum Dis 2005;64:899-905.
14. Kasukawa R, Shio K, Kanno Y, et al. Doppler ultrasonographic characteristics of superficial and deep- flow signals in the knee joint pannus of patients with rheumatoid arthritis. Ann Rheum Dis 2007;66:707-708.
15. Keen HI, Mease PJ, Bingham CO 3rd, Giles JT, Kaeley G, Conaghan PG. Systematic review of MRI, ultrasound and scintigraphy as outcome measures for structural pathology in interventional therapeutic studies of knee arthritis: focus on responsiveness. J Rheumatol 2011;38:142-154.

16. Vlad V, Libianu S, Berghea F, et al. US fact: RA knee pain is highly dependent on the level of synovial fluid. Ann Rheum Dis 2010;69Suppl 3:711.
17. Riente L, Delle Sedie A, Filippucci E, et al. Ultrasound imaging for the rheumatologist XXVII. Sonographic assessment of the knee in patients with rheumatoid arthritis. Clin Exp Rheumatol 2010;28:300-303.
18. Delle Sedie A, Riente L, Filippucci E, et al. Ultrasound imaging for the rheumatologist XXVI. Sonographic Assessment of the knee in patients with psoriatic arthritis. Clin Exp Rheumatol 2010;28:147-152.
19. D'Agostino MA, Conaghan P, Le Bars M, et al. EULAR report on the use of ultrasonography in painful knee osteoarthritis. Part 1: Prevalence of inflammation in osteoarthritis. Ann Rheum Dis 2005;64:1703-1709.
20. Conaghan P, D'Agostino MA, Ravaud P, et al. EULAR report on the use of ultrasonography in painful knee osteoarthritis. Part2: Exploring decision rules for clinical utility. Ann Rheum Dis 2005;64:1710-1714.
21. Clockaerts S, Bastiaansen-Jenniskens YM, Feijt C, et al. Cytokine production by infrapatellar fatpad can be stimulated by interleukin 1β and inhibited by peroxisome proliferator activator receptor α agonist. Ann Rheum Dis 2012;71:1012-1018.
22. Chao J, Wu C, Sun B, et al. Inflammatory characteristics on ultrasound predict poorer longterm response to intraarticular corticosteroid injections in knee osteoarthritis. J Rheumatol 2010;37:650-655.
23. Van Holsbeck M, Introcaso J. Musculoskeletal Ultrasound. 2nd edition, Mosby, St Louis 2001:160-165.
24. Ward EE, Jacobson JA, Fessell DP, Hayes CW, van Holsbeeck M. Sonographic detection of Baker's cysts: comparison with MR imaging. AJR Am J Roentgenol 2001;176:373-380.
25. Andonopoulos AP, Yarmenitis S, Sfoutouris H, Siamplis D, Zervas C, Bounas A. Baker's cyst in rheumatoid arthritis: an ultrasonographic study with a high resolution technique. Clin Exp Rheumatol 1995;13:633-636.
26. Rupp S, Seil R, Jochum P, Kohn D. Popliteal cysts in adults. Prevalence, associated intraarticular lesions and results after arthroscopic treatment. Am J Sports Med 2002;30:112-115.
27. Balint PV, Kane D, Wilson H, McInnes IB, Sturrock RD. Ultrasonography of entheseal insertions in the lower limb in spondyloarthropathy. Ann Rheum Dis 2002;61:905-910.
28. D'Agostino MA, Said-Nahal R, Hacquard-Bouder C, Brasseur JL, Dougados M, Breban M. Assessment of peripheral enthesitis in the spondylarthropathies by sonography combined with Power Doppler: a cross-sectional study. Arthritis Rheum 2003;48:523-533.
29. Wakefield RJ, D'Agostino MA. Essential applications of musculoskeletal ultrasound in rheumatology. 1st edition, Saunders, 2010:181-184.
30. Naredo E, Battle-Gualda E, Garcia-Vivar ML, et al. Power Doppler ultrasonography assessment of entheses in spondyloarthropathies; response to therapy of entheseal abnormalities. J Rheumatol 2010;37:2110-2117.
31. Frediani B, Falsetti P, Storri L, et al. Ultrasound and clinical evaluation of quadricipital tendon enthesitis in patients with psoriatic arthritis and rheumatoid arthritis. Clin Rheumatol 2002;21:294-298.
32. Naredo E, Acebes C, Moller I, et al. Clinical and epidemiological research: ultrasound validity in the measurement of knee cartilage thickness. Ann Rheum Dis 2009;68:1322-1327.
33. Esenyel C, Demirhan M, Esenyel M, et al. Comparison of four different intra-articular joint injection sites in the knee: a cadaver study. Knee Surg Sports Traumtol Arthrosc 2007;15:573-577.
34. Jones A, Regan M, Ledingham J, Pattrick M, Manhire A, Doherty M. Importance of placement of intra-articular steroid injections. BMJ 1993;307:1329-1330.
35. Toda Y, Tsukimura N. A comparison of intraarticular Hyaluronan injection accuracy rates between three approaches based on radiographic severity of knee osteoarthritis. Osteoarthritis Cartilage 2008;16:980-985.
36. Sibbitt WL Jr, Band PA, Chavez-Chiang NR, Delea SL, Norton HE, Bankhurst AD. A randomized controlled trial of the cost-effectiveness of ultrasound-guided intraarticular injection of inflammatory arthritis. J Rheumatol 2011;38:252-263.
37. Balint PV, Kane D, Hunter J, McInnes IB, Field M, Sturrock RD. Ultrasound guided versus conventional joint and soft tissue fluid aspiration in rheumatology practice: a pilot study. J Rheumatol 2002;29:2209-2213.
38. Hermans J, Bierma–Zeinstra SM, Bos PK, Verhaar JA, Reijman M. The most accurate approach for intra-articular needle placement in the knee joint: a systematic review. Semin Arthritis Rheum 2011;41:106-115.
39. Im SH, Lee SC, Park YB, Cho SR, Kim JC. Feasibility of sonography for intra-articular injections in the knee through a medial patellar portal. J Ultrasound Med 2009;28:1465-1470.
40. Recommendations for the medical management of osteoarthritis of the hip and knee: 2000 update. American College of Rheumatology Subcommittee on Osteoarthritis Guidelines. Arthritis Rheum 2000;43:1905-1915.
41. American College of Rheumatology Subcommittee on Osteoarthritis Guidelines. Guidelines for the management of rheumatoid arthritis: 2002 update. Arthritis Rheum 2002;46:328-346.
42. Cunnington J, Marshall N, Hide G, et al. A randomized, double-blind, controlled study of ultrasound-guided corticosteroid injection into the joint of patients with inflammatory arthritis. Arthritis Rheum 2010;62:1862-1869.
43. Gossec L, Dougados M. Intra-articular treatments in osteoarthritis: from the symptomatic to the structure modifying. Ann Rheum Dis 2004;63:478-482.
44. Hoppmann R, Hunt P, Louis H, et al. Medical student identification of knee effusion by ultrasound. ISRN Rheumatol 2011;2011:874-596.