Introduction: Musculoskeletal Ultrasound Indications and Fundamentals

Wolfgang A. Schmidt

Key Points

- Point-of-care ultrasound can be performed and interpreted by the rheumatologist in the clinic or at the bedside as part of the clinical examination for clearly distinguishing between normal and abnormal conditions and for differentiation of pathology.
- An increasing number of indications are emerging for performing ultrasound in daily rheumatology practice, as well as other musculoskeletal clinics.
- Musculoskeletal ultrasound is performed with linear transducers with frequencies of around 10 MHz (3–22 MHz). Higher frequencies provide better resolution but decreased depth.
- Anatomic structures are distinguished by different levels of echogenicity. For instance, bone is hyperechoic, synovium is midechoic, and fluid is anechoic.
- The sonographer should be aware of artifacts, and can use them to help identify anatomic structures (i.e., anisotropy can help to find tendons).

Introduction

Rheumatology is a fascinating specialty. Diagnosis strongly relies on history and clinical examination. Once a diagnosis is established, promising treatment options are available for the majority of rheumatologic conditions. Can ultrasound improve our clinical skills to examine a patient with suspected rheumatic disease? Yes, it definitely can! Combining history and clinical examination with ultrasound enables

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the rheumatologist to clearly define rheumatic disease entities. Ultrasound can be performed and interpreted by the rheumatologist at the point-of-care while interviewing and examining the patient. The added benefit of ultrasound with clinical correlation allows for expedited diagnosis and management, and targeted treatment (e.g., ultrasound-guided injections) of rheumatologic conditions with the potential for improved clinical outcomes, and decreased healthcare costs.

Indications for Ultrasound in Rheumatology

As rheumatology includes a wide range of diseases, ultrasound can be used for an increasing number of indications. The American College of Rheumatology has published a report of reasonable use of musculoskeletal ultrasonography in rheumatology clinical practice which provides a summary of clinical scenarios achieving positive evidence-based recommendations based on the current literature (Table 1) [1]. When considering the use of ultrasound in clinical practice, here are some questions to consider.

- **Does my patient have articular pathology?** Clinical findings are often ambiguous particularly in large joints, or in obese patients, which may only reveal painful impairment of the range of movement. It is also sometimes difficult to examine smaller joints, like the MTP joints. An examiner experienced in both sonography and the clinical examination can clearly distinguish normal from abnormal conditions.
- **If pathology is present, which structure is affected?** Ultrasound can easily distinguish synovitis, effusion, tenosynovitis, tendinitis, paratenonitis, enthesitis, bursitis, and fasciitis. The respective pathologies are explicitly described in chapter "Basic Ultrasound Pathology".
- **Does the abnormality represent inflammation?** Color power Doppler ultrasound allows visualization of the vascularity in synovial tissue, tendon sheaths, and tendons. Increased vascularity correlates with inflammation [2]. An inflamed joint is treated differently than a swollen uninflamed joint.
- **Has pathology already lead to structural damage?** If joint swelling is already obvious, ultrasound is more sensitive than x-ray for detecting erosive disease. It takes only seconds to screen the MCP 2, MCP 5, and MTP 5 joints for the presence of erosions [3].
- **Is it rheumatoid arthritis (RA) or osteoarthritis (OA)?** Ultrasound is particularly sensitive for detecting osteophytes. OA of MCP joints may mimic RA. Ultrasound can clearly differentiate between erosions and osteophytes in order to differentiate the two diseases [4].
- **Is it RA or psoriatic arthritis?** Psoriatic arthritis is characterized by multiple small erosions and proliferations different when compared to RA with larger erosions and less osteophytes [5]. Extra-articular manifestations of dactylitis and enthesitis can be differentiated.

Table 1 Summary of clinical scenarios for reasonable use of musculoskeletal ultrasound (MSUS) [1]

Indications for evaluation	Joints to evaluate	Level of evidence
Joint pain, swelling or mechanical symptoms without definitive diagnosis	Glenohumeral, acromioclavicular, sternoclavicular, elbow, wrist, metacarpophalangeal, interphalangeal, hip, knee, ankle, midfoot, and metatarsophalangeal	B
Mono- or oligoarthralgia without definitive diagnosis (consider subclinical inflammatory arthritis or enthesitis)	Glenohumeral, acromioclavicular, sternoclavicular, elbow, wrist, metacarpophalangeal, interphalangeal, hip, knee, ankle, midfoot, and metatarsophalangeal	B
New or ongoing symptoms of inflammatory arthritis without definitive diagnosis on clinical examination (assess inflammatory disease activity, structural activity, or other cause)	Glenohumeral, acromioclavicular, elbow, wrist, metacarpophalangeal, interphalangeal, hip, knee, ankle, midfoot and metatarsophalangeal, and entheseal	B
Hip pain or mechanical symptoms without definitive diagnosis	Intraarticular and periarticular lesions, and adjacent regional soft tissue structures of the hip	B
Periarticular pain without definitive diagnosis (consider tendon and soft tissue pathologies)	Shoulder, elbow, hand, hip, knee, ankle, and forefoot	B
Inflammatory-sounding entheseal, sacroiliac, or spine pain (enthesopathy)	Entheses	B
Shoulder pain or mechanical symptoms, without definitive diagnosis (consider underlying structural disorders)	Glenohumeral, acromioclavicular, rotator cuff	B
Inflammation, tendon, and soft tissue pathologies with regional mechanical symptoms, without definitive diagnosis	Shoulder, elbow, hand, wrist, hip, knee, ankle, and foot	B
Parotid and submandibular gland (consider Sjogren's disease)	Parotid and submandibular glands	B
Difficult to evaluate symptomatic joints due to fat or other soft tissue	Glenohumeral, acromioclavicular, elbow, wrist, hand, metacarpophalangeal, interphalangeal, hip, knee, ankle/foot, and metatarsophalangeal	C
Regional neuropathic pain without definitive diagnosis (e.g., median nerve entrapment)	Carpal tunnel, ulnar nerve at the cubital tunnel, and posterior tibial nerve at the tarsal tunnel	B
Guidance for articular and periarticular aspiration or injection	Synovial, tenosynovial, bursal, peritendinous, and perientheseal areas	A

(continued)

Table 1 (continued)

Indications for evaluation	Joints to evaluate	Level of evidence
Guidance for synovial biopsy procedures	Synovial areas	C
Monitoring disease activity and structural progression of joints in patients with inflammatory polyarthritis	Glenohumeral, acromioclavicular, elbow, wrist, hand, metacarpophalangeal, interphalangeal, hip, knee, ankle, foot, and metatarsophalangeal sites	B

- **Is it a pain syndrome, enthesitis, or tear?** Particularly the lateral humeral epicondyles, but also other anatomic areas like the medial femoral condyles and greater trochanter regions, are often painful either in the context of a musculoskeletal pain syndrome or because of inflamed anatomic structures. Tendons are hypoechoic and with increased hyperemia in enthesitis. Chronic inflammation leads to erosions, osteophytes and calcifications [6]. Degenerative tendon tears can be visualized as a potential pain generator.
- **Is it trauma or inflammation?** In addition to tendon and ligament tears, ultrasound can visualize bony irregularities or disruptions together with hyperperfused edema along the bone in fractures. Stress fractures of the metatarsal bones can be easily distinguished from primary inflammatory conditions [7].
- **Is there nerve pathology?** Nerves are well visualized with ultrasound. Abnormal nerves are thickened and hypoechoic proximal or distal to a compression [8]. The median nerve is most commonly examined for carpal tunnel syndrome. In addition to nerve pathology, ultrasound can detect causes for compression such as tenosynovitis, synovitis, ganglion cysts, and soft tissue masses.
- **Does my patient have gout?** Urate crystal deposits on the articular cartilage generate a hyperechoic, often irregular band, known as a "double contour sign;" its appearance and diameter can be similar to bone [9]. Intra-articular and extra-articular tophi have a hyperechoic "snow-storm" appearance. In addition, small hyperechoic spots, called "aggregates" or a "sugar in water clumps" appearance are often reported. Ultrasound is particularly valuable if there is no joint effusion amenable to aspiration and in patients with hyperuricemia without previous gout attacks in order to verify crystal deposition.
- **What about calcium pyrophosphate disease (CPPD)?** CPPD is often misdiagnosed as RA, gout or OA. Ultrasound shows characteristic hyperechoic rounded and linear densities in chondrocartilage (menisci, discus triangularis carpi) and in the hyaline cartilage, particularly in the intercondylar cartilage of the knee [10].
- **What is the reason for acute swelling of the lower leg?** Ruptured Baker's cysts are common due to arthritis of the knee. Ultrasound can easily and quickly show the pathology and differentiate swelling from peripheral edema, abscess formation, soft tissue masses, and deep vein thrombosis.
- **How can I correctly place a needle for aspiration and injection?** Ultrasound guidance increases accuracy and particularly allows for identification of small

amounts of abnormal fluid or synovitis that may have been missed with standard palpation-guided methods (see chapter "Ultrasound-Guided Injections").

- **Does my patient have polymyalgia rheumatica (PMR)?** Most untreated patients exhibit inflammation in the shoulder and hip region, such as subdeltoid and trochanteric bursitis, biceps tenosynovitis, and joint effusions. The specificity of classification criteria increases when incorporating ultrasound and hip ultrasound [11]. CPPD and calcific tendinitis may also be differentiated, which can be a mimicker for PMR.
- **Does the patient with PMR or with headache have giant cell arteritis?** Even small arteries like the temporal arteries can be visualized due to the excellent spatial resolution of ultrasound. Arterial walls are hypoechoic and swollen, known as a "halo sign" in cases of acute vasculitis (see chapter "Ultrasound in Vasculitis").
- **Is this primary or secondary Raynaud's phenomenon?** Likewise, ulnar, radial, and digital arteries are well visualized with ultrasound. Narrowing, stenoses, and occlusions are common in several rheumatic diseases such as systemic sclerosis, dermatomyositis, systemic lupus erythematosus, anti-phospholipid syndrome, or vasculitis [12].
- **Is this Sjögren's syndrome?** Ultrasound has become a specific, noninvasive tool in the diagnosis of Sjögren's syndrome. The parotid glands become inhomogeneous with characteristic hypoechoic areas representing dilated glandular ducts and lymph nodes [13].

Technical Fundamentals of Ultrasound

Ultrasound Waves

Ultrasound waves are generated by a transducer which represents the core of the ultrasound probe. The transducer consists of a disc with crystals of lead zirconate titanate. These crystals show a marked piezoelectric effect. They transform electrical potentials into mechanical vibrations and vice versa. When an electrical current passes through the crystals, the disc generates an ultrasound pulse. Conversely, when the disc receives an ultrasound wave that returns from the tissue, it will deform, and a voltage is generated on the transducer surface. Subsequently, the electronic potential is converted by a computer into an ultrasound image. The transducer functions as a receiver of returning ultrasound echoes for about 99.9 % of the time. The remaining 0.1 % of time it acts as an emitter of sound waves.

The term "ultrasound" refers to sound which is above the acoustic spectrum that can be heard by a human being. Humans can hear sound frequencies between 20 Hertz (Hz) and 20,000 Hz. 1,000,000 Hz equate to 1 Mega Hertz (MHz). Medical diagnostic ultrasound applies frequencies between 1 and 50 MHz.

Sound is a vibration that spreads as mechanical waves of compression and decompression. Sound waves travel with a velocity of 1540 m/s through air. They reach a distance of 10 cm after 0.000065 s. Within one second, about 1000 ultrasound waves can be emitted and received from an object at a distance of 10 cm from the ultrasound probe. Frequency (f) and wavelength (λ) are inversely proportional to each other, i.e., $f = 1/\lambda$. A higher frequency of the sound wave leads to a lesser penetration but to a higher resolution of structures. A lower frequency with longer wavelength leads to a greater penetration in the body, but resolution decreases.

The emitted waves are subject to transmission and reflection. Transmission occurs when a pulse passes through tissues. Reflection back to the source of the pulse occurs when an ultrasound pulse is reflected at an interface. The more two tissues differ in density from each other, the higher the amount of reflection; the more they are similar, the higher the amount of transmission. The boundary between two different tissues is called an acoustic interface. A marked interface exists between air and skin. If one places the transducer on the skin surface without using a coupling medium, i.e., ultrasound gel, only 0.1 % of the ultrasound pulse would be transmitted into the skin tissue and 99.9 % would be reflected by the skin surface. Therefore, with the use of ultrasound gel or water, a much higher amount of the ultrasound pulse penetrates into the tissue that will be examined. Liquids, like blood, urine, or synovial fluid do not reflect sound waves. When the surface of an object is flat and no air is present between the source and the object, almost all of the ultrasound waves will be reflected from the object at right angles [14, 15].

Ultrasound Energy

Ultrasound loses its energy as it propagates through the tissue. This loss of energy is called “attenuation”. There are three causes of attenuation: diffraction, scattering, and absorption. Diffraction refers to the bending of waves when they interact with obstacles in their path. Scattering means that waves are forced to deviate by nonuniformities of the tissue such as density fluctuations in fluids and inhomogeneous organs. Absorption means that acoustic energy is converted into heat energy. This implies warmth in body tissue. This phenomenon is applied for therapeutic ultrasound. Diagnostic ultrasound uses lower energies with a much lower effect on tissue temperature. A material or surface that absorbs sound waves does not reflect them. Absorption of a given material is frequency dependent. Attenuation results in echoes from deep body tissues being displayed less intense than those returning from superficial structures. A function of the ultrasound system, called time-gain control, corrects the attenuation and technically intensifies the echoes returning from deeper structures.

Ultrasound Modes

A-mode is the simplest mode of ultrasound. A single transducer scans a line through the body. Along this line the echoes are displayed on the screen as a function of depth. This mode is still sometimes used in ophthalmology to determine distances in the eye. The term B-mode stands for "brightness"-mode. This is the most commonly used mode in musculoskeletal ultrasound. It is also called gray scale ultrasound. An array of transducers simultaneously scans a plane through the body. The information is displayed as a two-dimensional image on the monitor. M-mode stands for "motion"-mode. This mode is most commonly used in echocardiography for determining the movement of cardiac structures. It can also show the pulsation of an artery. M-mode displays the depth of echo-producing interfaces along one axis and time along the second axis, recording motion of the interfaces towards and away from the transducer. Doppler modes are explained in chapter "Synovitis Evaluation".

Ultrasound Equipment

An ultrasound machine consists of a computer, a monitor, a keyboard and probes. Linear probes are capable of covering all indications for musculoskeletal ultrasound and most indications for vascular ultrasound. Abdominal ultrasound is mainly performed with curved array probes. Echocardiography is performed with sector array probes. Most linear probes are 4–5 cm long. Short probes with a length of about 2 cm are often called "hockey stick" or "footprint" probes because of their shape. They mainly serve to examine small superficial structures, or for assessing regions that are difficult to reach, such as to determine MCP joint pathologies in hammertoes.

To date, most probes offer a range of frequencies, e.g., 10–22 MHz, 6–18 MHz, or 3–13 MHz. Therefore, only one or two probes are needed to cover most of the indications that are relevant in rheumatology. Low frequencies of about 5 MHz are needed for examining deep structures such as hip joints or glenohumeral joints. High frequencies above 10 MHz are needed for examining superficial structures such as finger joints or temporal arteries.

The size of ultrasound machines differs considerably. Larger stationary equipment may provide higher image quality; however with improving technology, smaller, portable ultrasound equipment has allowed wide expansion of ultrasound use by the clinician, varying in size from a laptop computer to pocket-sized equipment. At this time, resolution for musculoskeletal indications is too low via pocket-sized equipment. Portable ultrasound machines often serve for orientation of office/bedside procedures, guided aspirations and injections and allow use of ultrasound in different offices, or clinic rooms.

How to Use Ultrasound Equipment: "Knobology"

When starting to use the ultrasound machine, the diversity of possible functions may be overwhelming. However, the sonographer needs to particularly know a few specific knobs. Figure 1 shows a panel of a high resolution stationary ultrasound machine. The arrangement of the operating components differs considerably between different ultrasound machines.

- **Power button (1)**: To date most ultrasound machines have it clearly visible in the front. In older machines the power button, or a second power button may be located in the back.
- **Button for starting a new examination** (**2**): After having finished the last examination, data needs to be saved. For examining a new patient, this button leads to a menu for entering the new patient data.
- **Select probe** (**3**): If you have more than one probe, pressing this button allows selecting the probe that is needed for the examination
- **Preset** (**4**): This button provides a variety of musculoskeletal, vascular, and other presets. Subgroups exist for example for small and large joints. The sonographer can create presets according to his or her preferences. Some smaller ultrasound equipment may already have defined presets that cannot be changed.
- **Frequency** (**5**): Modern transducers allow a choice between 3 and 5 frequencies. Some ultrasound machines indicate "resolution" for high frequencies and "penetration" for low frequencies. The sonographer should choose a higher frequency in order to receive a good resolution. If the image is too dark at the bottom of the image, the frequency needs to be lowered in order to increase the penetration. Some machines automatically adjust frequency.
- **Gain** (**6**): This button adjusts the acoustic power of the transmitted signals. When increasing the power, the ultrasound image becomes brighter. The brightness may be also changed in a specific image depth by the sliders on the right side,

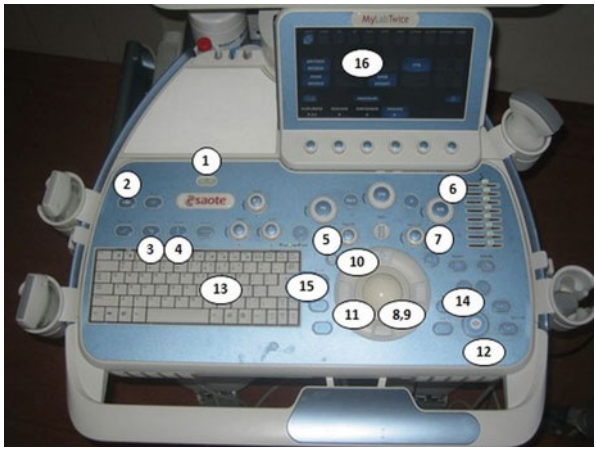

Fig. 1 Panel of an ultrasound machine showing important operating components. *1.* Power button, *2.* Button for starting a new examination, *3.* Select probe, *4.* Preset, *5.* Frequency, *6.* Gain, *7.* Image depth, *8.* Focus, *9.* Track ball, *10.* Select, *11.* Set, *12.* Freeze, *13.* Keyboard/Annotation, *14.* Save or print, *15.* Measure, *16.* Touch screen

also called “time gain compensation controls”. The sonographer needs to avoid too bright or too dark images (“over-gain” and “under-gain”).

- **Image depth** (**7**): It changes the field of view. The depth should be adjusted according to the size and depth of the examined structures.
- **Focus** (**8**): The focus needs to be localized close to the anatomic area of interest. Two or more foci may be applied. The frame rate (the number of images produced within 1 s) may decrease with increasing number of foci. The frame rate should be at least 12 images per second for achieving an adequate image quality. With the particular ultrasound equipment shown in the figures, the focus position is adjusted with the track ball. Some machines automatically adjust focus.
- **Track ball** (**9**): The track ball may have several functions e.g., adjusting the focus, placing a caliper or an arrow. When the freeze button is activated, scrolling the track ball allows review of the last sequences of the ultrasound examination.
- **Select** (**10**): Hitting this button leads to the different functions of the track ball.
- **Set** (**11**): This button serves as the enter button for confirming an action. It may be located on the left or on the right side of the track ball. This button is labeled as “enter” on some machines.
- **Freeze** (**12**): The button is pressed for acquiring a still image (“freeze”), e.g., for measurement or documentation and for starting the examination again (“unfreeze”).
- **Keyboard/Annotation** (**13**): By pressing a key on the keyboard, text can be written to label the ultrasound images, which is required for appropriate report documentation.
- **Save or print** (**14**): These buttons allow saving still images and videos electronically or printing out images.
- **Measure** (**15**): The sonographer can measure distances when using this button. Calipers appear (“+” at Fig. 1) that can be moved to an area of interest with the track ball.
- **Touch screen** (**16**): High end machines may provide additional functions that can be managed with a touch screen.

How to Sit and Hold the Probe: Ultrasound Ergonomics

Ultrasound is a safe imaging technique for the patient, but the sonographer may develop medical problems because of inappropriate posture when performing ultrasound on a regular basis. The sonographer should sit comfortably on a chair. Preferably, the chair should revolve. The monitor should be at or below eye level. If space and patient positioning allows, it can be adjusted in a way that both the sonographer and the patient can see the ultrasound image. The sonographer’s hand that is holding the probe should rest comfortably on the patient. It is important to hold the probe firmly with the first three or four fingers and place the fourth or the fourth and the fifth finger and the ulnar part of the hand on the patient for probe stability. The sonographer should be aware of

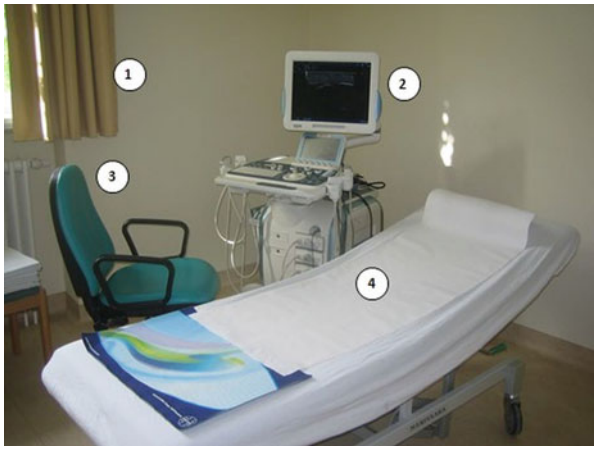

Fig. 2 Ultrasound workplace with *1.* Availability for dimming the daylight; *2.* Ultrasound machine with monitor adjusted to the level of the sonographer's eyes; *3.* Revolving chair with armrests, *4.* Height-adjustable examination bed

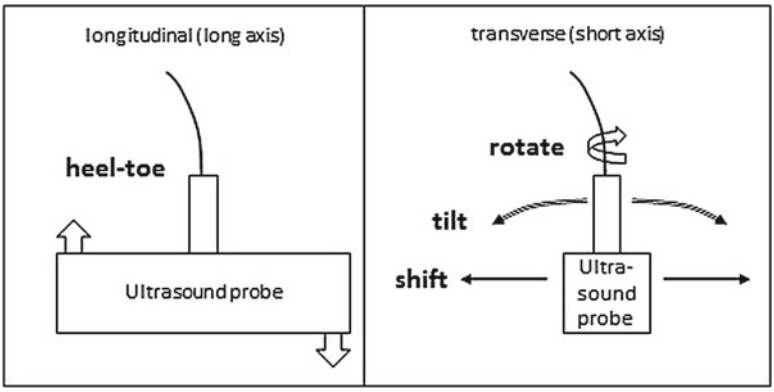

Fig. 3 How to move the ultrasound probe. Heel-toe, rotate, tilt, shift (axis change)

holding the arm comfortably to avoid rotator cuff problems of his/her own shoulders. Figure 2 shows an example ultrasound workplace.

The sonographer performs longitudinal (long axis) and transverse (short axis) views in relation to the body axis. Some views are oblique, e.g., for examining the sternoclavicular joints. The probe can be moved in different ways (Fig. 3).

- Heel-toe: Angling the probe in a longitudinal plane, e.g., for avoiding anisotropy of the biceps tendon.
- Shift (or change the axis): Moving the probe side-to-side, e.g., for examining the full length of the biceps tendon.
- Tilt (or rock): Angling the probe in a transverse plane, e.g., for achieving that the probe is parallel to an anatomic structure.
- Rotate: Change direction around the axis of the probe, e.g., for adjusting the probe parallel to a structure, e.g., a needle.

How Anatomic Structures Appear on an Ultrasound Image

Structures can be isoechoic to soft tissue or deeply localized fat tissue, hyperechoic (brighter), hypoechoic (darker) or anechoic (black) (Fig. 4). Fat and connective tissue are heterogeneous. Skin is isoechoic or slightly hyperechoic. Tendons show a fibrillar pattern in longitudinal views. They are hyperechoic if located parallel to the probe and hypoechoic when insonation is not perpendicular because the reflected waves divert and miss the transducer. This phenomenon is called "anisotropy" (see below). Nerves are hypoechoic with a more dotted appearance than tendons (Figs. 5 and 6). The epineurium and fascicles of the nerve are typically hyperechoic in a honeycomb-like pattern. Fluid is anechoic or hypoechoic. Ultrasound may display physiologic amounts of fluid in normal joints or pathologic amounts of fluid (effusions) in inflamed joints. Synovium and synovial proliferations are hypoechoic. Cartilage is hypoechoic or anechoic. The bone surface is hyperechoic. Ultrasound waves cannot penetrate through bone, and therefore musculoskeletal ultrasound cannot depict structures underneath the bone surface. Figure 4 shows different types of echogenicity.

1. Soft tissue (fat pad)—isoechoic.
2. Bone—hyperechoic.
3. Skin—isoechoic.
4. Fat tissue—hypoechoic with hyperechoic septae.
5. Muscle—hypoechoic with hyperechoic septae, (fibrillar pattern in longitudinal view, "starry night" pattern in transverse view).

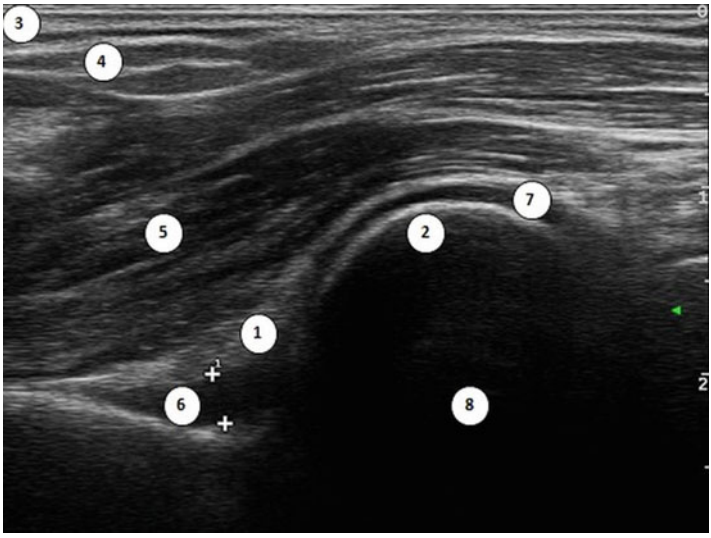

Fig. 4 Anterior longitudinal ultrasound image of an elbow with different types of echogenicity: *1.* Soft tissue (fat pad)—isoechoic, *2.* Bone—hyperechoic, *3.* Skin–isoechoic, *4.* Fat tissue–hypoechoic with hyperechoic septae, *5.* Muscle–hypoechoic with hyperechoic septae, *6.* Small amount of intra-articular fluid—anechoic, compressible, *7.* Cartilage—anechoic, *8.* Area under bone surface—anechoic

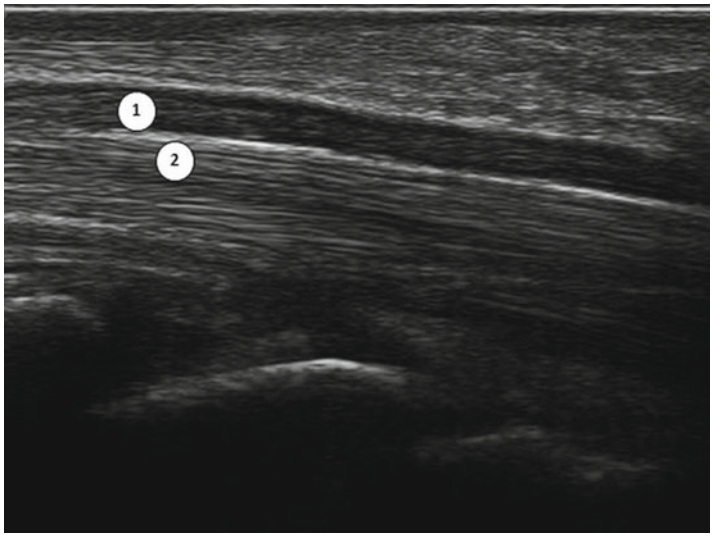

Fig. 5 Longitudinal palmar view of a wrist with *1.* Median nerve (hypoechoic) and *2.* Flexor digitorum tendons (fibrillar pattern)

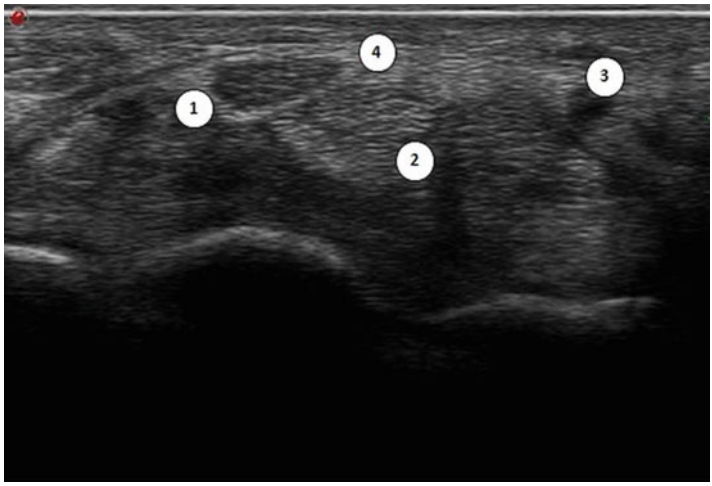

Fig. 6 Transverse palmar view of the wrist showing the different appearance of *1.* Median nerve, *2.* Flexor tendons, *3.* Flexor retinaculum and *4.* Radial artery (anechoic)

6. Small amount of intra-articular fluid—anechoic, compressible.
7. Cartilage—anechoic.
8. Area under bone surface—anechoic.

Common Artifacts

When beginning to perform ultrasound, artifacts may cause some confusion because non-existing structures or pathology are seen on ultrasound images [16]. With increasing ultrasound experience artifacts may become helpful, for instance in distinguishing a tendon from another structure by anisotropy.

Anisotropy

Tendons are strongly reflecting the sound waves. If tendons are not parallel to the probe, the reflected waves are not traveling back to the transducer (Fig. 7). The tendon appears hypoechoic. The proximal part of the biceps tendon is located more anteriorly than the distal part of the biceps tendon. By heel-toeing the probe, i.e., by pressing the distal end of the probe down, the probe becomes parallel to the tendon with increasing echogenicity of the tendon (Fig. 8).

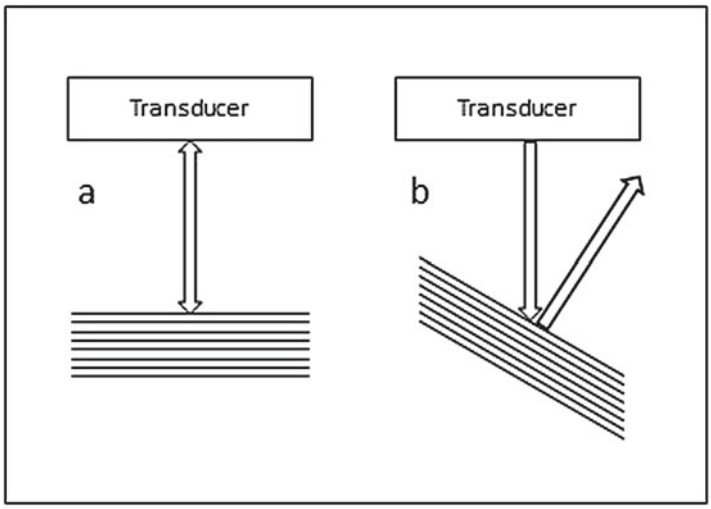

Fig. 7 (**a**) The tendon is parallel to the probe. The sound waves are reflected towards the probe. The tendon appears bright (hyperechoic). (**b**) The tendon is not parallel to the probe. The sound waves are reflected away from the probe. The tendon would appear dark (hypoechoic)

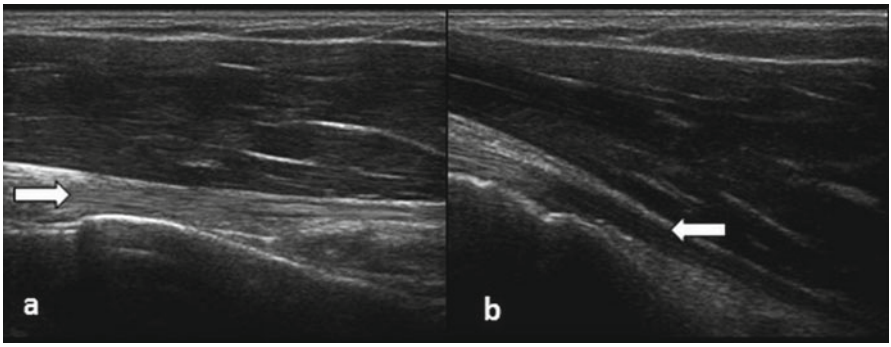

Fig. 8 Ultrasound image of a biceps tendon (*arrows*) (**a**) without and (**b**) with anisotropy

Posterior Acoustic Shadowing (Attenuation Artifact)

Sound waves are totally reflected or absorbed by bone or calcifications. The area below is anechoic. It is impossible to visualize structures below bone or calcifications (Fig. 9).

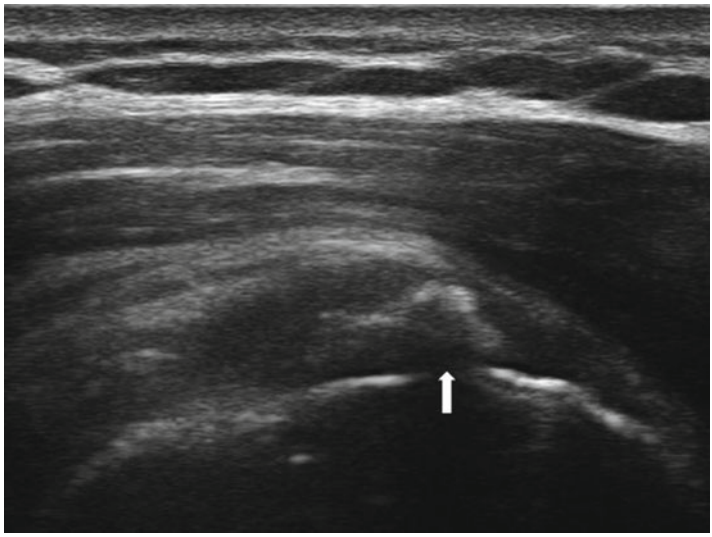

Fig. 9 A calcification of the supraspinatus tendon causes posterior acoustic shadowing mimicking a cortical break of the humeral head (*arrow*). The humeral head itself causes acoustic shadowing. The area below the bone is anechoic

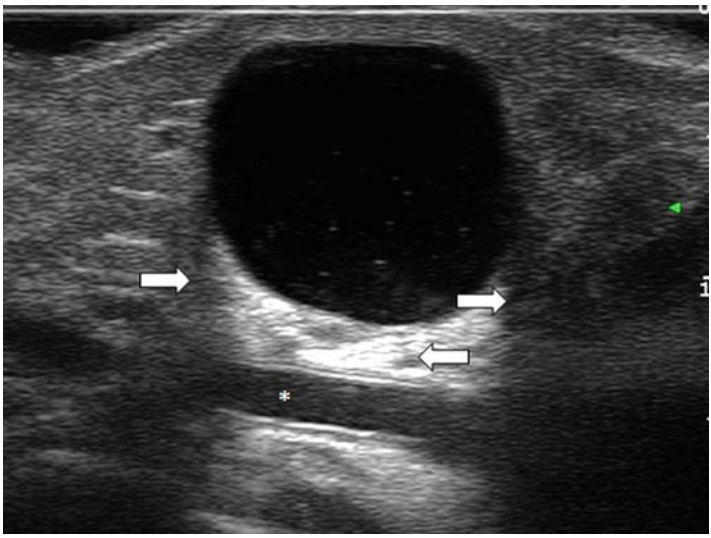

Fig. 10 Longitudinal image of a ganglion cyst at the volar side of a wrist. The echogenicity is increased below the anechoic ganglion (←). The radial artery (*) is much better visualized in this region. The two hypoechoic lines on both sides of the posterior acoustic enhancement represent lateral edge shadowing (→)

Posterior Acoustic Enhancement

Anechoic or hypoechoic lesions, such as fluid collections, cause reduced attenuation, i.e., transmission is increased with increased brightness of structures below the lesion (Fig. 10).

Lateral Edge Shadowing

This artifact is a thin acoustic shadow that appears behind edges of anechoic, hypoechoic, or curved structures, often tendons, but also fluid collections (Fig. 10). Sound waves encountering a curved surface at a tangential angle are scattered and refracted. Due to loss of energy, hypoechoic shadows appear.

Posterior Reverberation

When ultrasound encounters two parallel highly reflective surfaces, the sound waves are bounced back and forth between the two layers before returning back. The transducer detects a prolonged traveling time and displays additional images in

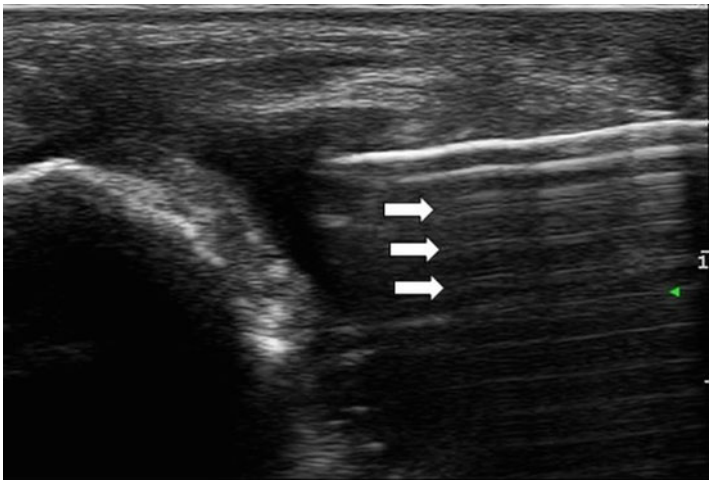

Fig. 11 Reverberation artifacts (→) below an injection needle

deeper layers. Figure 11 shows reverberation by an injection needle. The sound waves bounce back and forth between the two sides of the needle with additional layers below the needle.

If the reverberation artifact appears more continuously below a metal surface, it is called a "**ring-down artifact**" (Fig. 12). If these artifacts are very thin with a marked difference in acoustic impedance to the surrounding tissue, they are also called "**comet tail artifacts**" (Fig. 13). These artifacts appear below metal nails and screws as well as below air. They are common in pulmonary fibrosis and may help diagnose pulmonary involvement in systemic sclerosis.

Mirror Image

This artifact is relevant both in gray scale and color Doppler ultrasound. If a structure is located adjacent to a strong reflector, it may be duplicated on the other side of the reflector. The reflector causes additional sound waves that bend towards the neighboring anatomy, from where they are bounced back towards the strong reflector and return to the transducer (Fig. 14).

Further artifacts with Doppler ultrasound are covered in chapter "Synovitis Evaluation".

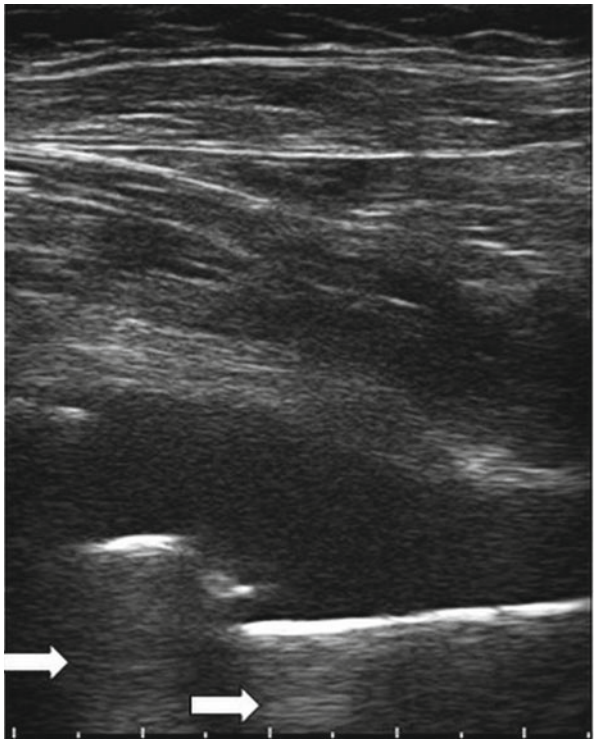

Fig. 12 Ring-down artifacts below a hip joint prosthesis (→)

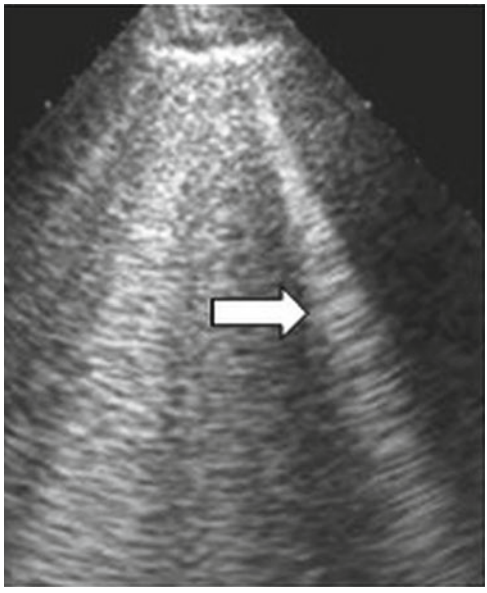

Fig. 13 Comet tail artifact in pulmonary fibrosis (→)

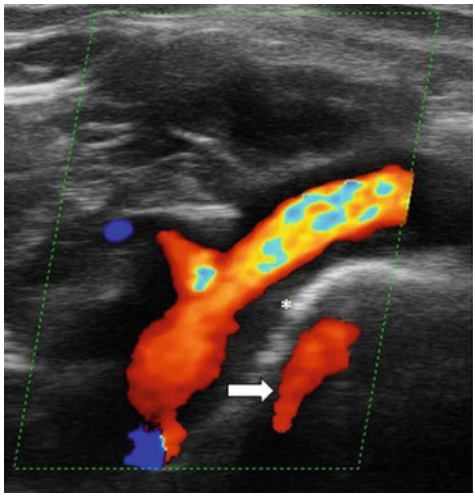

Fig. 14 Proximal left subclavian artery in large-vessel giant cell arteritis (see chapter "Ultrasound in Vasculitis"). The clavicle (*) serves as strong reflector. The color signal of the subclavian artery is mirrored on the other side of the clavicle

Conclusion

Point-of care ultrasound allows the clinicians to use their history and exam skills correlating with an ultrasound examination of specific joint regions to help identify pathology and or confirm disease activity for better evaluation and management of musculoskeletal and rheumatologic conditions. Techniques to improve image acquisition and recognition of artifacts are important to the accurate interpretation of the ultrasound examination.

Review Questions

1. Which of the following is *not* a typical indication for ultrasound in rheumatology?

   (a) Search for erosions at MCP 2, 5 and MTP 5 joints in early arthritis.
   (b) Detect bone marrow edema of sacro-iliac joints in spondyloarthritis.
   (c) Estimate the inflammatory activity in the synovium of a swollen joint.
   (d) Distinguish osteoarthritis from rheumatoid arthritis lesions in finger joints.
   (e) Distinguish stress fracture from synovitis of MTP joints.

2. Which rheumatic disease has *no specific ultrasound finding*?

   (a) Sjögren's syndrome.
   (b) Carpal tunnel syndrome.
   (c) Small vessel vasculitis.
   (d) Large-vessel giant cell arteritis.
   (e) Chondrocalcinosis (CPPD).

3. Which of the following statements is true?

   (a) Medical ultrasound refers to sound frequencies only between 10 and 20 Hz.
   (b) Higher ultrasound frequencies lead to better penetration.
   (c) The transducer functions as an emitter of sound waves for most of the time.
   (d) The loss of energy of ultrasound when traveling through tissue is called "attenuation".
   (e) Diagnostic ultrasound implies more heat in the body tissue than therapeutic ultrasound.

4. Which of the following statements about ultrasound modes is true?

   (a) A-mode is the ideal mode for examining joints.
   (b) B-mode stands for "brightness" mode.
   (c) M-mode is used for static structures.
   (d) 3D mode is essential for musculoskeletal ultrasound.
   (e) Doppler mode is useless for vascular imaging.

5. Which of these frequencies is most adequate for the respective anatomic region?

   (a) 1 MHz for ankle joint.
   (b) 2 MHz for elbow joint.
   (c) 10 MHz for wrist joint.
   (d) 100 MHz for MCP joint.
   (e) 200 MHz for DIP joint.

6. Which of the following statements on ultrasound equipment is true?

   (a) The preset button serves for raising and lowering of the monitor.
   (b) The gain adjusts the acoustic power of transmitted signals.
   (c) The frequency can be adjusted by the time gain compensation controls.
   (d) More foci increase the image frame rate.
   (e) Decreasing the frequency allows for higher image resolution.

7. How should the sonographer hold and move the probe?

   (a) The sonographer's fingers should not touch the patient's skin.
   (b) The monitor should be above the sonographer's eye level.
   (c) The sonographer's arm should be elevated while performing the examination.
   (d) For performing the heel-toe maneuver, the probe is angled along the transverse axis.
   (e) Tilting the probe helps adjust it parallel to an anatomic structure.

8. Which echogenicity corresponds correctly to a tissue?

   (a) Fluid is hyperechoic.
   (b) Soft tissue is anechoic.
   (c) Bone is midechoic.
   (d) Synovitis is hypoechoic.
   (e) Hyaline cartilage is hyperechoic.

9. Which statement about anisotropy is true?

   (a) Anisotropy is due to reverberation.
   (b) Anisotropy is typically found in vessels.
   (c) The anatomic structure becomes dark when being parallel to the transducer.
   (d) Anisotropy may be avoided by rotating the probe.
   (e) Anisotropy may lead to misdiagnosis of fluid collections.

10. Which statement on other artifacts is true?

   (a) Posterior acoustic enhancement leads to increased echogenicity below a cyst.
   (b) Mirror images only occur in gray scale images.
   (c) Due to lateral edge shadowing, the lateral areas of an ultrasound image are darker.
   (d) The area below bone is anechoic because of posterior reverberation.
   (e) A comet tail usually appears in fluid.

Answers

1. (b) Detect bone marrow edema of sacro-iliac joints in spondyloarthritis.
2. (c) Small vessel vasculitis.
3. (d) The loss of energy of ultrasound when traveling through tissue is called "attenuation."
4. (b) B-mode stands for "brightness" mode.
5. (c) 10 MHz for wrist joint.
6. (b) The gain adjusts the acoustic power of transmitted signals.
7. (e) Tilting the probe helps adjust it parallel to an anatomic structure.
8. (d) Synovitis is hypoechoic.
9. (e) Anisotropy may lead to misdiagnosis of fluid collections.
10. (a) Posterior acoustic enhancement leads to increased echogenicity below a cyst.

References

1. McAlindon T, Kissin E, Nazarian L, Ranganath V, Prakash S, Taylor M, et al. American College of Rheumatology report on reasonable use of musculoskeletal ultrasonography in rheumatology clinical practice. Arthritis Care Res. 2012;64:1625–40.
2. Larché MJ, Seymour M, Lim A, Eckersley RJ, Pétavi F, Chiesa F, et al. Quantitative power Doppler ultrasonography is a sensitive measure of metacarpophalangeal joint synovial vascularity in rheumatoid arthritis and declines significantly following a 2-week course of oral low-dose corticosteroids. J Rheumatol. 2012;37:2493–501.

3. Wakefield RJ, Gibbon WW, Conaghan PG, O'Connor P, McGonagle D, Pease C, 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.
4. Iagnocco A. Imaging the joint in osteoarthritis: a place for ultrasound? Best Pract Res Clin Rheumatol. 2010;24:27–38.
5. Riente L, Carli L, Delle Sedie A. Ultrasound imaging in psoriatic arthritis and ankylosing spondylitis. Clin Exp Rheumatol. 2014;32(1Suppl 80):S26–33.
6. Terslev L, Naredo E, Iagnocco A, Balint PV, Wakefield RJ, Aegerter P, et al. Defining enthesitis in spondyloarthritis by ultrasound: results of a Delphi process and of a reliability reading exercise. Arthritis Care Res (Hoboken). 2014;66:741–8.
7. Banal F, Gandjbakhch F, Foltz V, Goldcher A, Etchepare F, Rozenburg S, et al. Sensitivity and specificity of ultrasonography in early diagnosis of metatarsal bone stress fractures: a pilot study of 37 patients. J Rheumatol. 2009;36:1715–9.
8. Cartwright MS, Walker FO. Neuromuscular ultrasound in common entrapment neuropathies. Muscle Nerve. 2013;48:696–704.
9. Thiele RG, Schlesinger N. Diagnosis of gout by ultrasound. Rheumatology (Oxford). 2007;46:1116–21.
10. Filippou G, Filippucci E, Tardella M, Pertoldi I, Di Carlo M. Adinolfi A. Extent and distribution of CPP deposits in patients affected by calcium pyrophosphate dihydrate deposition disease: an ultrasonographic study. Ann Rheum Dis. 2013;72:1836–9.
11. Macchioni P, Boiardi L, Catanoso M, Pazola G, Salvarani C. Performance of the new 2012 EULAR/ACR classification criteria for polymyalgia rheumatica: comparison with the previous criteria in a single-centre study. Ann Rheum Dis. 2014;73:1190–3.
12. Schmidt WA, Krause A, Schicke B, Wernicke D. Color Doppler ultrasonography of hand and finger arteries to differentiate primary from secondary forms of Raynaud's phenomenon. J Rheumatol. 2008;35(8):1591–8.
13. Wernicke D, Hess H, Gromnica-Ihle E, Krause A, Schmidt WA. Ultrasonography of salivary glands – a highly specific imaging procedure for diagnosis of Sjögren's syndrome. J Rheumatol. 2008;35:285–93.
14. Schmidt WA, Backhaus M. What the practising rheumatologist needs to know about the technical fundamentals of ultrasonography. Best Pract Res Clin Rheumatol. 2008;22:981–99.
15. Bruyn GA, Schmidt WA. Introductory guide to musculoskeletal ultrasound for the rheumatologist. Houten, NL: Bohn Stafleu van Loghum/Springer; 2011. ISBN 978-90-313-9206-3.
16. Taljanovic MS, Melville DM, Scalcione LR, Gimber LH, Lorenz EJ, Witte RS. Artifacts in musculoskeletal ultrasonography. Semin Musculoskeletal Radiol. 2014;18:3–11.